THE
GEOLOGICAL MAGAZINE
VOLUME LXV.

No. I.—JANUARY, 1928.

ORIGINAL ARTICLES.

On the Deposition of Calcareous Tufa in a Mountain Stream at Binn, Canton Valais, Switzerland.

By W. A. Macfadyen, M.C., M.A., F.G.S.

(PLATE I.)

AGGRADATION of the bed of a river is a well-known and common phenomenon in certain circumstances, but in the present case a mountain stream, whose grade is so steep that waterfalls are present, is found flowing along the top of a well-marked but very irregular ridge of tufa. This is found in a little stream near the village of Binn, known to mineralogists for the array of rare minerals which occur in metamorphosed Triassic dolomite not far away up the valley of the Binna.

The usual way of approach is from the Rhone valley up the road leading through the beautiful gorge of the Twingen, at the eastern end of which, on the left of the road, is a little stone-built shrine of " St. Niklaus ". Some 180 metres[1] past the shrine, and somewhat less than a kilometre below Binn village, a streamlet dashes down the mountain side almost into the ear of the passing pedestrian, and, diving under the road, joins the turbulent waters of the Binna river below, close to its junction with the Langbach.

Interest is aroused in this stream (which seems to be nameless) by the observation that just above the road it is flowing not in a little valley cut in the country rock, but over an irregular mass of calcareous tufa (Pl. I, Fig. 1). The stream is found to arise full-grown in a spring which gushes out beneath steeply sloping turf a few metres from the base of a 10-metre cliff, and perhaps 30 metres above the road level. The cliff is of the country rock, a micaceous schist. The spring gives rise to a stream about a foot wide, which flows for the first 30 metres of its course through a grass field in a normal bed with no deposition of tufa. From m. 30 to m. 95 the bed is abnormal, and is composed of a deposit of dull yellowish calcareous tufa which forms a discontinuous ridge rising to some 1·3 metres above the general level of the ground; on top of or over this ridge the stream flows, sometimes in a narrow groove. From m. 30 to m. 45 the stream bed is hardly appreciably raised by the tufa, but from this point to m. 95 deposition is well marked, and irregular masses of tufa are found especially in connexion with broken waterfalls, which are individually up to 6 metres in height. From m. 52 to m. 60 the stream runs partly in a conspicuous trough of tufa well raised above the normal ground level (Pl. I, Fig. 2). About m. 68 a fall begins which ends close to the road at m. 76, this stretch being noteworthy for the quantity of tufa found. The road has been constructed over the stream from m. 77 to m. 82 of the latter's course, and past it the steep gradient continues to m. 95. From m. 95 to the outfall into the Binna at about m. 200 the stream runs in a normal bed through less steeply sloping fields, and tufa is not deposited, the fragments found being rolled and evidently derived from higher up. The total drop from source to end of the stream is of the order of 50 metres.

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[1] All the distances mentioned were determined by pacing, difficult to do on a steep slope, and the heights were estimated by eye; both are therefore only approximate.

ANALYSES.

A representative sample of the tufa was analyzed [1] with the following results:—

	Per cent.
Organic matter	1·54
Carbon dioxide	40·28
Calcium oxide	51·27
Magnesium oxide	1·03
Silica	4·81
Iron oxide and alumina	1·30
Sulphuric acid	trace
	100·23

This agrees with analyses of "Calcareous Sinter" from some American springs cited by F. W. Clarke (1).[2]

The spring water was free from taste and smell, and evolved no gas bubbles when the sample bottle was slightly warmed. The following analysis is of a water sample taken at the source at 7.30 a.m. on 26th August, 1926; temperature of water 7° Centigrade.

	Parts per 100,000.
Chlorine	0·25
Sulphuric acid (SO_3)	2·26
Nitric acid	absent
Silica	trace
Iron oxide and alumina	0·07
Calcium oxide	8·74
Magnesium oxide	2·01
Total solids	21·4

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[1] The analyses of the tufa and of the water were kindly made for me by Dr. H. E. Cox, M.Sc., Ph.D.(Lond.), F.I.C., Public Analyst for the Borough of Hampstead.

[2] Figures in parentheses refer to bibliography at the end of this paper.

Calculation of these figures by Chase Palmer's method (2) gives the following properties :—

Primary salinity . . .	1·6
Secondary salinity . . .	13·4
Primary alkalinity . . .	*nil*
Secondary alkalinity . . .	85·0

TYPE OF WATER.

It is of interest to inquire into the origin of the water, which may be deduced with a considerable degree of probability from a comparison of its analysis with those of other waters. For this purpose the analysis has been recalculated in accordance with Clarke's usual method of statement. The other two analyses are taken from Clarke (*op. cit.*).

	Spring at Binn.	(" B," p. 101) *River Aar at Bern.*	(" E," p. 100) *Schliersee, Bavaria.*
CO_3 . . .	50·1	48·6	50·7
SO_4 . . .	12·7	14·6	11·2
Cl . . .	1·2	0·1	0·6
NO_3 . . .	*nil*	—	—
Ca . . .	28·4	30·5	26·9
Mg . . .	5·7	4·7	5·8
Na(+ K) . .	0·8	0·2	2·1
SiO_2 . . .	trace	1·3	1·6
Al_2O_3 Fe_2O_3 } . .	0·1	—	1·1
	100·0	100·0	100·0
Salinity, parts per million . .	214	213	190

The water is, in fact, practically identical with several lake and river waters cited by Clarke. Regarding the " Analyses of water from Bavarian and Austrian lakes ", which include that of the Schliersee quoted above, Clarke states (p. 101) : " These lakes are surrounded by sedimentary rocks " and " Magnesium . . . is decidedly above its average amount in lake and river waters, a fact which is due to the presence of much dolomite in the lake region ". It seems clear, therefore, that the water in the spring and stream under consideration is ordinary meteoric water which has derived its solids held in solution from contact with dolomitic strata. There is no evidence that the water ever contained greater quantities of lime and carbon dioxide under pressure, since this would normally manifest itself by gas evolution and tufa deposition at the mouth of the spring, and neither occurs.

DEPOSITION OF THE TUFA.

The mode of occurrence of the tufa and the analysis of this and of the stream water make it clear that it is in fact formed of solids deposited from this water. The low concentration of dissolved solids and the absence of any traces of free carbon dioxide at the source make it certain that the first explanation that would occur (namely the throwing down of calcium carbonate previously held in solution by carbon dioxide under pressure greater than atmospheric) cannot be correct in this case. The same reasoning must also apply to certain other cases where this facile explanation has been given.

A close examination of the tufa shows that it has been deposited mainly round moss, whose porous texture it often retains. Moss is plentiful in and bordering the stream bed where the tufa is being deposited, and solution of a piece of tufa in hydrochloric acid yielded a good crop of moss fragments. The moss has been identified by Mr. H. N. Dixon as *Cratoneuron commutatum* (Hedw.) Roth, (*Hypnum commutatum* Hedw.). He writes (*in lit.*) that it is commonly seen in various parts of France and Switzerland about the base of fountains and artificial waterfalls where the rock used is limestone ; it builds up tufa in a manner somewhat similar to the Burmese moss.[1]

This building up of tufa by mosses is no new observation, but it has not always been borne in mind in descriptions of tufa occurrences. Only in one or two of the papers referred to by the writer is any attempt made to give even partial analyses of the water or tufa.

In 1851 von Schauroth (3) gave a short account of tufa formation in the Thuringer Wald, which he ascribed to the action of moss. Later, F. Cohn (4) wrote a detailed account of a well-known Italian occurrence, in which the moss in the present case is noted as a tufa builder. He observed that although the water was rich in hydrogen sulphide he was unable to detect any trace of sulphide in the tufa.

Planchon (5) has studied calcareous tufa at Montpellier and noted the presence of moss in connexion therewith, though he did not recognize the tufa-extracting power of the moss. Two points in his book are worthy of note, firstly the low solids content of the water, 48 parts of calcium bicarbonate per 100,000, and secondly his observation that " à son point d'émergence, près de la source, l'eau peu agitée ne produit aucune incrustation calcaire . . ."

C. commutatum in connexion with tufa is described by various authors, some of whom indicate the relationship between them, while others do not. Of the former Klähn (6) has described tufa in the Wutachtal which is deposited from a water of the high solids content of 352 parts per 100,000, this consisting mainly of calcium sulphate and sodium chloride.

It may be noted that Geikie (7), after giving a short account of the phenomenon, states in a footnote that " In Scotland *Hypnum commutatum* is a leading sinter-former ".

Professor J. W. Gregory (8) has described some interesting cases of tufa formation in waterfalls on certain rivers of Dalmatia and Bosnia. There is no mention of the occurrence of moss, and a statement on p. 540 implies that the deposition is considered to be due to obstructions of the country rock in the river bed causing, by their disturbance of the water, "the decomposition of the bicarbonate and the deposition of the carbonate of lime as calcareous tufa." On p. 543 it is interesting to note that "In the Topolje Falls . . . the cliff projects where the volume of water is greatest, as the deposition of tufa is most rapid there." No analysis of the river water is given. The description is sufficiently close in certain particulars to the Binn and Burma occurrences, for instance, for the suggestion to be made that a moss may be mainly responsible for the tufa.

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[1] See below.

Finally, curious weirs of calcareous tufa in some of the rivers in the Northern Shan States of Burma have been described by La Touche (9), and they have since been found to be due to the abstraction of tufa by the moss *Barbula inflexa* (Dub.) C. Müller. The circumstances detailed are closely paralleled in two particulars in the Binn stream. La Touche states that "The growth [of the tufa] is most rapid along the lip of the fall, where the water is most agitated". A full analysis of the water of the Burmese rivers referred to is not given, but it is stated that the water contains only 22·3 parts of dissolved solids per 100,000.

It is clearly established that certain mosses abstract calcium carbonate from natural waters which contain this salt in solution even in very low concentration, and may perhaps even synthesize it, given the calcium ion associated with other acid radicles, as is the case for instance with the domestic hen for her eggshells. Secondly the activity of the moss is most intense at falls, where the water is in most rapid motion and subjected to marked aeration.

I am indebted to Dr. H. Hamshaw Thomas for help, and to Mr. H. N. Dixon, M.A., F.L.S., who very kindly identified the species of moss in question, and from whom (through Dr. Thomas) I obtained several references to other cases. For much helpful criticism I have to thank Mr. A. G. Brighton, M.A., F.G.S.

BIBLIOGRAPHY.

(1) Clarke, F. W. "The Data of Geochemistry", 5th ed.: *United States Geological Survey*, Bull. 770, 1924.
(2) Palmer, Chase. "The Geochemical Interpretation of Water Analyses": *United States Geological Survey*, Bull. 479, 1911.
(3) von Schauroth. *Zeit. d. deutsch. geol. Ges.*, vol. iii, 1851, p. 135.
(4) Cohn, F. "Ueber die Entstehung des Travertin in den Wasserfallen vcn Tivoli": *Neues Jahrb. f. Min.*, 1864, p. 580.
(5) Planchon, G. *Étude des Tufs de Montpellier*, Paris, 1864.
(6) Klähn, H. "Die Petrogenese der Kalktuffe nebst einigen sich daraus ergebenden geologischen Problemen": *Geol. Archiv, Königsberg*, Heft 6, Bd. 2, 1923, p. 298.
(7) Geikie, A. *Text-book of Geology*, 4th ed., 1903, vol. i, p. 611.
(8) Gregory, J. W. "Constructive Waterfalls": *Scottish Geog. Mag.*, vol. xxvii, 1911, p. 537.
(9) La Touche. "Geology of the Northern Shan States": *Mem. Geol. Surv. India*, vol. xxxix, pt. ii, 1913, pp. 326, 327.

On the Occurrence of Dark Apatite in some British Rocks.

By W. F. Fleet, M.Sc., Ph.D., F.G.S. and F. Smithson, B.Sc., F.G.S.

Apatite in Midland Sediments.

In a paper (1)[1] by one of us (W. F. F.) reference is made to the occurrence in Midland sediments of apatite grains having dark purplish, often pleochroic, cores or nuclei. From an examination of the heavy minerals in Midland rocks ranging from Cambrian to Trias it is evident that these peculiar apatite grains occur at several horizons. Discoloured grains appear in the Cambrian quartzite and apatite of smoky tint in the Old Red Sandstone. In the Carboniferous rocks, dark-banded grains varying in tint from yellowish-brown to smoky-purple and occasionally pleochroic, occur with fair frequence. Similar grains are particularly noticeable in the Gornal Sandstone, which lies in the lower part of the Middle Coal Measures of South Staffordshire. An hexagonal cross section of apatite from this rock, with a dark core, was figured in the paper referred to above. Similar grains occur, though rarely, in the Enville and Bunter Sandstones, but increase in frequency in the Lower Keuper Sandstone. The dark-coloured "cores" may be sharp-edged or rather indefinite in contour, narrow or broad, and variable as regards depth of tint. Clear-cut bands or stripes of dark colour are exceptional.

Apatite in the Old Red Sandstone of the Cardiff Area.

Dr. A. Heard and Mr. R. Davies (2) record that apatite is very abundant in the Old Red Sandstone of the Cardiff area, and find that in the Upper Group many of the grains contain cores which are either opaque, or more commonly, brown and pleochroic. They presume that the sediments were introduced by a huge river which drained a pre-Cambrian land-mass lying to the north-west.

Apatite in Granite of Jersey.

Mr. A. W. Groves (3) records the common occurrence, in the "Newer" granites of Jersey, of apatite crystals having central cores of inclusions. Such grains are, presumably, of a similar type to those described above.

Apatite of the Leinster Granite.

Whilst examining samples of the Leinster Granite recently, one of us (F. S.) has observed the occurrence of apatite grains with dark cores. Professor W. J. Sollas (4) has already recorded the occurrence in the Leinster Granite of apatite grains in which there is a central pleochroic core with a faint violet tint, but further work has shown that the apatite cores are frequently dark and, in some of the larger grains, actually opaque.

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[1] Figures in parentheses refer to the list of works given at the end of this paper.

This type of apatite does not occur in all the granites, for in the centre of the granite mass the apatite is quite clear and colourless. At Killiney and other places near the western margin of the intrusion grains with dark cores occur together with grains that are entirely colourless. The outlines of the cores vary considerably. In some grains the boundaries are sharply defined, so that the grain has the appearance of a dark prism surrounded by a layer of the colourless mineral. When such a grain lies on its basal plane the core is seen to be hexagonal in section. In other grains the boundary of the core is indefinite or irregular, in which case the tint is usually faint. Sometimes there is a dark, well-defined core, surrounded by a zone of faintly tinted apatite. The colour varies from black to a purplish or brownish tint, and pleochroism is usually noticeable in all except the opaque cores.

Near the source of the Liffey a fragment of rock extremely rich in biotite was found to contain these grains in great abundance. The rock was not found *in situ*, but as the neighbouring granite is traversed by lenticles or bands of schists it probably represents a portion of a xenolith or enclave. Most of the apatite grains from this rock contain dark, sharply defined, cores, and occasionally two dark nuclei are seen lying parallel to one another within the same grain. Chemical tests to discover the nature of the colouring matter have so far been unsuccessful. Bead tests give no result, and when the grains are treated with nitric acid they dissolve, leaving only the faintest trace of dust.

LEINSTER AS A POSSIBLE SOURCE OF APATITE IN WELSH AND ENGLISH SEDIMENTS.

Definite descriptions, other than those indicated above, of these peculiar apatite grains in either igneous or sedimentary rocks appear to be lacking, and it seems advisable to draw attention to the matter in order that any future observation of such grains may be recorded with a view to tracing the source of the detrital grains of Welsh and English rocks.

From the facts cited above it appears conceivable that some of these grains have been derived from the Leinster area. The Leinster Granite was considered by Professor G. A. J. Cole (5) to be early Devonian. It is certain, however, that the granite suffered erosion during Devonian times, and, as the apatite grains with dark cores are frequent near the margin of the granite, they would certainly be available as detrital material during part, at least, of the Devonian period.

The appended table is a comparison of the material found by Messrs. Heard and Davies in the Welsh Old Red Sandstone with constituents of the Leinster Granite and the neighbouring schists and quartzites, and supports the suggestion that Irish rocks may have contributed to the Old Red Sandstone deposits. The possibility that Midland sediments may have shared directly or indirectly in a similar contribution is at least worthy of consideration. It must be borne in mind, however, as previously stated by one of us (W. F. F.) (6, 7), that there is reason to believe that the Midland Bunter sediments did not derive their mineral suites as a whole from the source which supplied the Old Red Sandstone of the Western Midlands.

OLD RED SANDSTONE (Cardiff Area).	OCCURRENCE IN LEINSTER.
Microcline Oligoclase Orthoclase (?)	In granite.
Quartzite pebbles	Quartzites of Bray Series (Cambrian ?).
Mica-schist pebbles	Zone of Contact Metamorphism.
White mica Chlorite (? after biotite)	Muscovite and biotite in the granite.
Ilmenite and leucoxene	Abundant in schists and in Bray Series.
Garnet	Abundant in schists and aplites.
Tourmaline	Abundant in schists.
Zircon	In granite and abundant in Bray Series.
Purple zircon	Common in Bray Series.
Rutile	In Bray Series.
Apatite	Abundant in granite.
Magnetite (rare)	Rare in granite and schists.

REFERENCES.

(1) FLEET, W. F. "The Chief Heavy Detrital Minerals in the Rocks of the English Midlands": GEOL. MAG., Vol. LXII, 1925, pp. 102, 106, 110, 113, 116, 120, 123.

(2) HEARD, A., and DAVIES, R. "The Old Red Sandstone of the Cardiff District": *Q.J.G.S.*, vol. lxxx, 1924, pt. iv, p. 501.

(3) GROVES, A. W. "The Heavy Minerals of the Plutonic Rocks of the Channel Islands: I. Jersey": GEOL. MAG., Vol. LXIV, 1927, p. 244.

(4) SOLLAS, W. J. "Contributions to a Knowledge of the Granites of Leinster": *Trans. Roy. Irish Acad.*, vol. xxix, 1891, pp. 434–5.

(5) COLE, G. A. J., and HALLISSY, T. *Handbook of the Geology of Ireland*, London, 1924, p. 20.

(6) FLEET, W. F. "Petrological Notes on the Old Red Sandstone of the West Midlands": GEOL. MAG., Vol. LXIII, 1926, p. 514.

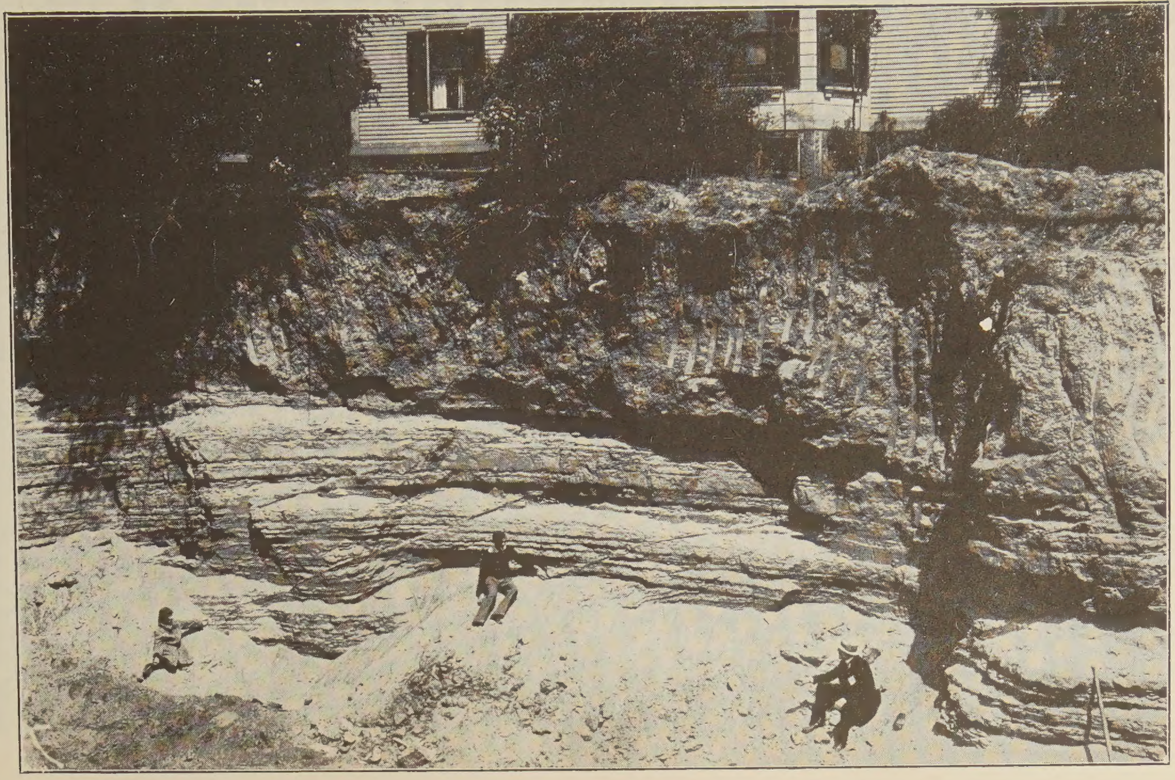
(7) —— "The Heavy Minerals of the Keele, Enville, 'Permian,' and Lower Triassic Rocks of the Midlands, and the Correlation of these Strata": *Proc. Geol. Assoc.*, vol. xxxviii, 1927, p. 40.

Till on Overthrust Gravels.

By Professor ALFRED C. LANE, Tufts College, Massachusetts.

(PLATE II.)

THE plate which accompanies this article, showing till overriding and overthrusting in its readvance the gravels on which the yard of Harvard University is built, is of a temporary exposure. This was made in putting in a large apartment house at the northwest corner of Arlington Street and Massachusetts Avenue, North Cambridge. The camera was pointed north. Realizing its unusual character, I got my colleague, Professor M. S. Munro, who is a virtuoso with the camera, to take it, and have used it as a postcard to friends. One of them, my old teacher, William Morris Davis, said it was unexcelled, and urged its publication. That is the occasion of



TILL OVERRIDING GRAVEL PLAIN AT CAMBRIDGE, MASS., U.S.A.

[*To face p. 8.*

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this article, for, when I came to think of it, to obtain such a photograph required an unusual combination of circumstances :—

(1) The artificial excavation ;

(2) A strike that suspended work at the critical time (it is an ill wind that blows no one good) ;

(3) Just such conditions of wind and drying out as to bring out the different beds in the sands. The coarser ones dry and crumble more rapidly, while the fine hold the dampness and stand out. We might add :—

(4) A man living on the street (myself) to appreciate it, and

(5) A friend who is an excellent photographer.

I might have sent it to the *Journal of Geology* in Chicago, which has been keen in such matters, but as it seemed to me to throw light on a recent little discussion, and resemble some illustrations in the GEOLOGICAL MAGAZINE,[1] I offer it.

The question as to the origin of drumlins is not a new one. I well remember presiding at a discussion in the Michigan Academy of Science when T. C. Chamberlin and I. C. Russell debated the naming of certain forms which Russell had found in working for the Geological Survey of Michigan.[2] These were of the shape of drumlins, but he thought they were carved out by "ice erosion from a previously deposited tillsheet". He called them drumlins still, whereas Chamberlin insisted that if they were formed as Russell stated they might be called "drumloids", but that the term drumlins should be confined to forms built up by accumulation under the ice. This origin by construction Leverett [3] confirmed for certain Michigan drumlins by a study of the concentric arrangement of the slabby boulders which they contained, but they were not the ones studied by Russell.

It will be noted, however, that both sides agreed that they were ice-formed.

The region of the illustration is that of the Boston Basin. In this there are large beds of brick clay closely studied years ago by my lamented friend, Professor J. B. Woodworth of Harvard University.[4]

He called attention to the fact that a readvance of the ice had contorted these brickclays which formed in the water out in front of the ice, and that they pass under the till of the drumlins which are a marked feature of the Boston basin in a number of places.

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[1] Professor J. K. Charlesworth, "The Postglacial History of Drumlins": GEOL. MAG., Vol. LXIV, April, 1927, pp. 157–63. See also Pl. IX of K. E. Williams' article on the glacial drifts of Western Cardiganshire, May, 1927, pp. 205–26.

[2] *Seventh Report, Michigan Acad. of Sci.*, 1905, p. 37 ; see also *Bull. Geol. Soc. Am.*, 16, 1906, pp. 577–8, and 17, 1907, p. 707 ; *Am. Geologist*, 35, 1905, pp. 177–9 ; *Science*, 21, 1905, pp. 220–1 ; *Scientific Am. Suppl.*, 59, 1905, 24326 ; *Mich. Geol. Sur. Report*, 1904, pp. 33–112, and 1906, pp. 7–91.

[3] *Bull. Geol. Soc. Am.*, 16, 1906, p. 577.

[4] *Seventeenth Ann. Rep. of the U.S. Geol. Surv.*, 1896, pt. i, a paper with N. S. Shaler and C. F. Marbut on the glacial brick clays of Rhode Island and South-Eastern Massachusetts, especially chap. iii, figs. 42 and 43, and pp. 995 to 997.

The clay is also overlaid generally with more or less gravel. All around Harvard University it has been beautifully shown this summer (1927) in making deep cuts for a heating plant. But it has not been so clear what the relation of these gravels to the drumlins was, whether they were outwash after or before the readvance, though Woodworth showed that in some cases the gravel also antedated the till of the drumlins. Thus Davis welcomed the light which the section shown in Plate II threw on the matter. It is clear that the " Fresh Pond Moraine " which runs from Fresh Pond under the Harvard observatory to the point where Plate II was taken and seems to connect with drumlins in Somerville, has readvanced over and overthrust the gravel which extends south to and all around Harvard Square.

We thus have an upper till and a lower till with brickclays and gravels between and a section of which the descriptions by Williams [1] of the glacial drifts of Cardiganshire much remind one.

While, therefore, I agree with Professor Charlesworth as to the glacial formation of drumlins or drumloids, to say that drumlins " invariably " [2] lie beneath the recessional accumulations is to go too far.

The Boston drumlins have been bevelled slightly by the sea, but the underlying brickclays are not " varved " or banded, and therefore according to de Geer and Antevs,[3] formed after the ice had so far retired that there was open sea or at least tide water to the east. Thus even these clays were formed in the closing stages of the ice age, and the readvance marked by the overthrusts shown in Plate II may be coeval with that described by Antevs at Amherst as occurring during the year 4800 (from an arbitrary starting point of 3000 when the ice front was at Hartford, Connecticut), after having left it some 350 years before.

The overlying till is very much firmer and, as shown in the photograph, frequently overhung, while the sands beneath dried out and crumbled away. This led to one very serious accident. In drying a vertical jointing developed quite in contrast with the horizontal or slightly inclined bedding of the sands and gravels. The vertical lines shown in Plate II are, however, due to the teeth of the excavator. The weight of two pieces of the till as fresh as I could get it, not dried out, but not perceptibly damp, was by the paraffin dip method [4] 2·0 respectively 2·1 tons per cubic meter, about what I have repeatedly found from glacial brick clays. This means about 40 per cent pore space. A fresh specimen of the underlying sands weighed

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[1] Loc. cit.,

[2] Loc. cit., p. 160.

[3] E. Antevs, " The recession of the last ice sheet in New England " : *Am. Geographical Society*, Research Ser. No. 11, New York City, pp. 3 and 7 as to salt water, pp. 77 to 81 as to readvance.

[4] *Bull. Geol. Soc. Am.*, 33, 1922, p. 356 ; see also Lefax 13–18, Table for the recognition of Minerals, xviii, and A. F. Melcher, *Trans. A.I.M.E.*, lxv, 1921, p. 470.

1·465 tons, which when thoroughly wet rose to 1·85. This is about the upper range of porosity (47·64 per cent), so that in spite of the overthrusting there was no compacting. However, this is practically at the extreme edge of the till. The thrust faults are at least nine in number (see Fig. 1), more crowded to the east, i.e. toward the edge. Their general dip is about 28° to N. 30° W. as determined by R. S. Knappen and myself. But as they approach the contact of the till and the gravel they flatten and tend to become parallel to it. Toward the west, where the till is thicker, they become more irregular and there are some wedge blocks and contorted sands, with faults dipping both ways as shown in Fig. 1.

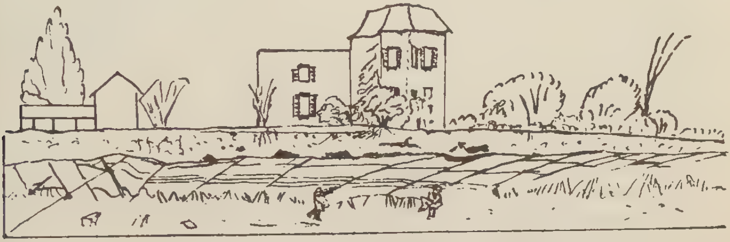

Fig. 1—Sketch combining a number of photographs (see Plate II) of a temporary exposure at the N.W. corner of Massachusetts Avenue and Arlington Street, Cambridge, Massachusetts, about a mile from Harvard University, showing till overlying overthrust gravels.

Near the bottom of the excavation, about 20 feet from the surface, considerably below the till, was a sharp line of secondary oxidation, black with limonite and very sharp against the light grey sands and gravels above, but fading gradually through rusty brown into a yellower sand below. This evidently marks the course of circulating oxidizing waters, from which the till protected the upper layers. It may be of recent origin and mark circulation from some foundation or well down to some sewer.

As I studied the exposures I was much impressed with the fact that if we correlate the readvance with that mentioned at Amherst it was only a matter of three or four hundred years, yet such an exposure taken by itself, especially if it occurred in consolidated and metamorphic rocks, I might easily take as evidence of an important unconformity, separating two geological cycles, instead of being a mere incident of the ice retreat of the last ten to fifteen thousand years.[1]

EXPLANATION OF PLATE II.

Temporary section 20 feet high exposed in excavating foundation at the north-west corner of Massachusetts Avenue and Arlington Street, Cambridge, Mass., U.S.A. A layer of till overlies bedded sand and gravel, plain, disturbed by numerous overthrust faults.

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[1] Cf. E. Antevs, *Retreat of the last Ice-sheet in Eastern Canada*, Memoir 146 of the Geol. Survey of Canada (1925), p. 90 and before and after.

Geological Studies in the Dublin District. I. The Heavy Minerals of the Granite and the Contiguous Rocks in the Ballycorus District.

By F. Smithson, B.Sc., F.G.S.

FROM the southern shores of Dublin Bay there stretches to the south-west a broad granite intrusion with rocks of supposed Ordovician age on both sides of it. These rocks are metamorphosed near the granite, and the belt of metamorphism is wider on the south-east than on the north-west side, indicating, no doubt, that the plane of junction dips more steeply on the latter side. Near Dublin the Lower Carboniferous rocks rest unaltered upon the granite. On the south-east side, in the northern part of the county of Wicklow, the belt of Ordovician rocks is only some 2 miles wide, and a large area of supposed Cambrian rocks lies between it and the sea. Around the hill of Carrickgollogan a patch of similar rocks appears incongruously in the middle of the Ordovician belt. After a study of the region to the south of Dublin one seems to be naturally drawn towards this small area around Carrickgollogan, for it presents a problem, the key to which may explain the geological structure of a much wider area.

In the present paper an account is given of the petrology of the district around Ballycorus, with special reference to the heavy minerals, but the sections dealing with the petrology of the granite refer to a wider area, extending from Kingstown to Kippure, a distance of about 12 miles.

THE DISTRICT AROUND BALLYCORUS.

The district here described is an area 2½ miles by 3 miles, on the south-east margin of the Leinster Granite, about 10 miles from the city of Dublin.

The relief of the region is varied. Although only about 100 feet above sea-level along its north-east margin, the general altitude increases towards the south-west. Along the junction of the granite and the schist, which here trends N.E.–S.W., the ground is more or less elevated. In the north-east this ridge is not conspicuous, but at Rathmichael it rises suddenly and continues to the south-west margin of the map at an elevation of 600 to 800 feet. At one point only is it broken, where the deep gorge of the Scalp was cut through in Glacial times. Northwards from this ridge the ground slopes down to form the valley of the Loughlinstown River, and then rises in a less conspicuous ridge cut by two small dry gaps, the Dingle Glen and Glenamuck. On the other side of the line of junction the land slopes down to the south-east, except at the middle of the ridge. Here, near Ballycorus, elevated ground extends to the south-east, culminating in the quartzite hill of Carrickgollogan.

Although most of the lower ground is thickly covered with drift, there are good exposures of the solid rocks on the higher ground and in the dry gaps.

THE GRANITE.

The essential minerals of the granite (Sollas[1] 1889 and Mem. 112) are quartz, microcline, orthoclase, soda-lime felspar (varying from oligoclase to albite), muscovite, and biotite. In addition, Sollas recognized zircon and apatite as accessory minerals.

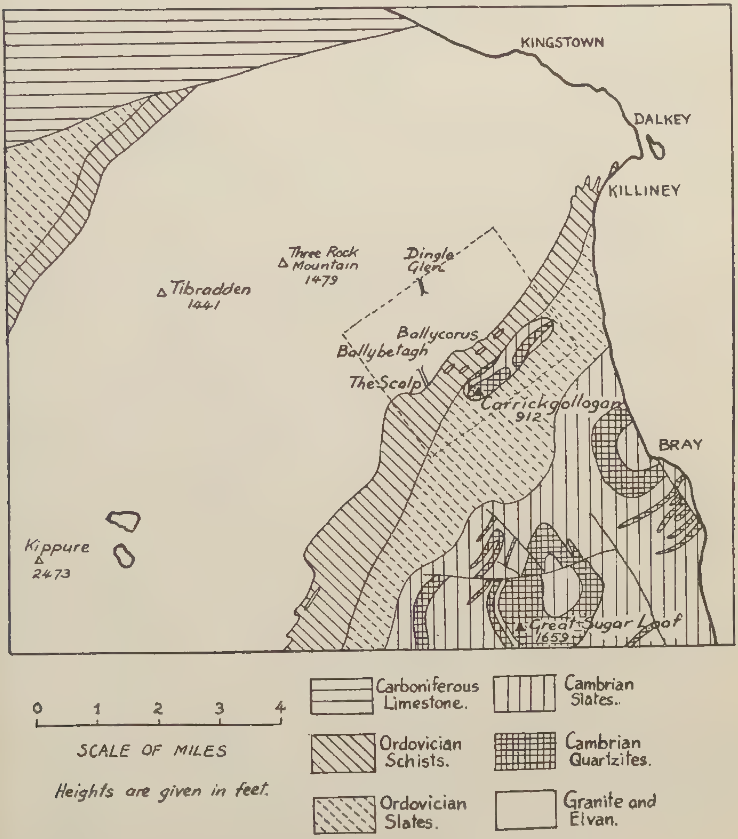

FIG. 1.—Map of the District South of Dublin.

In the Memoir to Sheet 112 a number of minerals are listed as occurring in the granite, including, evidently, vein minerals:

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[1] References to literature are given only by the name of the author and the date. The full reference can be found from the list given at the end of the paper.

barytes, copper pyrites, killinite, sphene (?), beryl, corundum (?), orthite (?), spodumene, cassiterite, epidote, pinite, tourmaline, cerussite, hyalite (?), and rutile. To these must now be added: anatase, brookite, garnet, ilmenite, limonite, magnetite and monazite.

As the accessory minerals include those which were the earliest to crystallize from the magma they will be considered first.

It is of interest to note that the heavy minerals form an exceptionally small proportion of the rock. Samples of granite from Shap Fell, Devonshire, the Brocken and Stockholm with similar treatment give a much greater yield of heavy minerals than the Leinster Granite.

Apatite is present in all the heavy residues and is by far the most abundant accessory mineral of the granite. The grains are prismatic in habit, and are very commonly more than 0·3 mm. in length.

Frequently the crystals of apatite contain inclusions of a mineral of prismatic habit, high refractive index and birefringence, and positive in sign. In a few cases pyramidal terminations and a characteristic zonal structure leave no doubt that the mineral is zircon, but in other cases the mineral may be monazite. Cavities occur in the apatite, filled with liquid and a gas bubble.

Usually the apatite is an ordinary fluor-apatite, clear and colourless; but two peculiar types occur. One type, found at the Dingle Glen, is faintly magnetic, and, although clear and colourless when viewed by transmitted light, a cluster of grains viewed by reflected light appears faintly yellowish. Qualitative tests have shown the presence of phosphorus, calcium, fluorine and iron, whilst chlorine has been found to be absent. The iron is not present in inclusions, nor is it merely present in a coating, for even after the grains have been partly dissolved they still contain iron. The iron is certainly small in amount, and the faintly magnetic property of the mineral suggests that it is probably in the ferrous condition, replacing part of the lime.

Another type already noticed by Sollas (1889) has a pleochroic purplish core. In the granite a small percentage of the apatite grains are of this type, the tint being sometimes rather faint; but about 2 miles south of Kippure the present writer has found fragments of rock in which apatites with dark cores are abundant. The rock is extremely rich in biotite and accessory minerals, and may be of xenolithic origin. The darkest cores from this rock are quite black, but in the smaller grains the purple colour is distinct. An occasional basal grain shows that the core is hexagonal in section, that is to say, it is a crystal of coloured apatite around which colourless apatite has crystallized. An attempt has been made to discover the nature of the colouring matter, but without success.

Zircon is everywhere present, but never abundant. Grains more than 0·2 mm. in length or 0·08 mm. in width are rare. The crystals are usually well formed and prismatic in habit, the ratio of length to breadth being usually between 2 : 1 and 6 : 1. In most of the crystals only one prism (110) is present; but sometimes (100) is also developed. The prisms are terminated by pyramid faces, either (111) or steeper forms. Zoning is not infrequent. Cruciform twinning has been observed only in one case.

In the heavy residues a number of crystals have been observed with a central rounded core. The appearance is that of a partly resorbed crystal or a worn detrital grain of zircon, around which more of the mineral has crystallized in optical continuity with the original portion.

Monazite has not hitherto been recorded, yet it appears to be present in all the localities from which samples have been taken. In the granite from the Three Rock Mountain the grains of supposed monazite are small, and the identification is, therefore, doubtful; but in all other cases the mineral has been recognized by the absorption spectrum, and, where the mineral was obtained in sufficient quantity, by chemical tests.

Monazite is usually more abundant than zircon in the heavy residues. Not only are the grains more numerous but they are, on an average, a little longer and much stouter than the zircons. Inclusions of small zircon prisms are not uncommon. The monazite is pale yellow in colour, and occurs as stumpy prismatic crystals with poorly defined faces or as small ovoid grains.

Anatase is not uncommon in those granites in which the biotite has undergone chloritization. Indeed, in the absence of other titaniferous minerals in most of the samples, it seems likely that the titanium dioxide was originally a chemical constituent of the biotite.

The anatase occurs both as basal plates and as bipyramidal grains, but frequently growth in restricted space has caused a flattening on one of the prism faces. The mineral is usually blue, but at Killiney it is pale yellow. The largest grains measure 0·2 mm.

Many small crystals of this mineral were obtained by collecting large crystals of muscovite from the granitic sand at Kippure, and carefully splitting the mica along its cleavage. In addition to anatase small crystals of zircon and monazite were obtained together with minute grains of pyrite or chalcopyrite.

Brookite is rare, only a few grains having been found in the granite of Killiney and Kingstown.

Rutile is rare, and has only been found in the granite of Killiney, Kingstown, and the Scalp. It varies from a pale to a dark brown.

The iron minerals, *ilmenite*, *magnetite*, and *pyrite* are all scarce. The latter has usually been altered to *limonite*, which is found in the form of pyritohedra.

Barytes, which is common as a vein mineral at Ballycorus, is found at the Scalp disseminated through the granite.

Garnet and *tourmaline*, which are abundant in the aplites, are also present in some of the granites.

The essential minerals have been very fully described by Sollas (1889), and only a few remarks are needed here.

Biotite is present in variable amounts throughout the granite. It belongs, as Sollas has shown, to the variety *haughtonite*, in which the amount of ferrous oxide is high and that of magnesia is low. The mineral usually occurs intergrown with muscovite. Frequently the plates of biotite are rounded and show signs of corrosion, which has been taken as evidence that the biotite was formed, then partly re-dissolved and formed again as muscovite (Sollas, 1889). But as the biotite of the schists also appears to be haughtonite it is worth considering whether this mineral may not have been derived from the schists by absorption into the magma.

The biotite is frequently altered to *chlorite*, which, like the original mineral, contains small crystals of zircon (and monazite ?) surrounded by pleochroic haloes. The chlorite also contains crystals of high refractive index and high birefringence, which appear to be anatase. Since the fresh biotite very rarely contains inclusions, it seems reasonable to suppose that the anatase is derived from the biotite itself.

Muscovite is always in excess of biotite. Near the margin of the granite the crystals of muscovite are rarely large and usually distorted. But near the Dingle Glen, at Three Rock Mountain, Kippure and other places, large hexagonal plates of muscovite are abundant in the granite. They do not appear to be oriented in any definite manner. These plates, when split, yield an interesting set of heavy minerals : biotite, apatite, zircon, monazite, anatase and, more rarely, rutile, brookite and ilmenite. Examination of the mica itself reveals the presence of another kind of inclusion in the form of a thin bluish grey film with an outline (hexagonal, rhombic or triangular) always consistent with hexagonal symmetry.

LEUCOCRATIC DIFFERENTIATION PRODUCTS OF THE GRANITE.

The leucocratic differentiation products include coarse-grained pegmatites and the finer-grained rocks occurring as veins in the granite and as minor intrusions in the schists.

The pegmatite veins present some interesting minerals. Beryl is common at the Scalp, where it occurs in thin veins. The mineral is inconspicuous on account of its strong resemblance to the felspars, being either milky white or only a very pale green. Killinite, which was first described as occurring at Killiney as an alteration product of spodumene, also occurs in veins at Rathmichael. But the most interesting pegmatites are those of

Glencullen Mountain, where in a single hand-specimen one may see quartz, microcline, muscovite, spodumene, arsenopyrite, beryl, and garnet. Spodumene may be fairly widespread in this area, for it has been found in sands derived from the granite at Kippure, Lough Bray Upper, east of Kippure, and at Carrickmines.

The minor intrusions have been usually referred to as elvan. They are leucocratic and normally do not differ from many of the aplite veins in the granite. It is perhaps best to confine the term elvan to the larger of the minor intrusions, and to refer to the smaller lenticles, dykes and veins, whether they occur in the granite or in the schists, as aplites.

The leucocratic rocks differ from the granite in that biotite, except in the case of one intrusion, is entirely absent, and with biotite the iron minerals and titaniferous minerals disappear also. *Garnet*, *tourmaline* and *apatite* are frequently abundant in the heavy residues, whilst *monazite* and *zircon* are scarce.

THE CAMBRIAN.

The Cambrian rocks of the counties of Dublin and Wicklow are of a distinctly arenaceous type and offer a marked contrast to the Ordovician. The thick layers of quartzite evidently represent a period or periods of shallow water deposition, and even many of the slates are distinctly sandy, shallow water deposits. Moreover, there are no signs of contemporaneous vulcanicity, and no intrusive rocks penetrate the Cambrian. Even around Carrickgollogan, where these rocks are near the Leinster Granite, they are readily distinguishable from the Ordovician grits of the area by the absence of garnet and secondary tourmaline.

Numerous exposures of the quartzite occur in the present area, whilst the slates are only occasionally met with, as, for example, where the ground has been trenched to form field boundaries. The following petrological details, therefore, refer chiefly to the quartzites and to such of the slates as are exposed in the quartzite quarries.

Three important areas of quartzite are recognized :—

(*a*) Around Carrickgollogan, where the rock occurs over an area of about 1,200 yards by 300 yards.

(*b*) Around the quarries south of Shankill Castle, where, on account of the thick glacial drift, the extent of the area cannot be determined.

(*c*) A belt of quartzite to the north-west of Carrickgollogan, about 60 yards in width and nearly a mile in length.

These areas will be referred to as the Carrickgollogan, Shankill Castle and North-West areas respectively.

The quartzites have been described by Sollas (1892) who recognized the presence of *zircon* and *tourmaline*. To these must now be added *leucoxene*, *ilmenite*, *rutile*, *anatase*, and *epidote*.

The quartzite consists essentially of quartz grains cemented together, usually by secondary quartz, but in some cases by limonite or haematite. The ferruginous cements commonly occur near joints or cracks in the rock.

The grains of *quartz* usually average from 0·2 mm. to 0·4 mm. in diameter. A thin section rarely shows many grains larger than 1·0 mm. in diameter, whilst the largest measurement taken was 1·62 mm.

The *zircons* are frequently large; the largest measured was 0·312 mm. in length, but grains more than 0·2 mm. in length are not very common. The colourless zircons present every gradation from the unworn prismatic grain with perfect pyramidal terminations to the well-worn, rounded grain. Purple zircons, though less common, are frequently large, and are always in a much worn condition. In some of the heavy residues the zircons consist of fragments of a shattered grain re-cemented with quartz.

Leucoxene is about as abundant as zircon, and these two minerals form the bulk of the heavy residues in most cases. The leucoxene is evidently an alteration product of *ilmenite*, which is now quite rare. The colour of the leucoxene grains is white to yellowish, and in some cases the smooth porcelainous surface clearly represents the shape of the original rounded grain of ilmenite. In other cases the outline is irregular. The largest grains are nearly 0·3 mm. in diameter.

Tourmaline is fairly common in the form of flat rounded grains, brownish or bluish in colour. Most of the grains are larger than 0·1 mm. in diameter, whilst the largest measured was 0·223 mm. on its long axis.

Rutile is not common in any of the quartzites, and it appears to be absent from some. It occurs usually in the form of dark brown oval grains, rarely in the form of prismatic grains. The largest measured was 0·135 mm. in length.

Anatase, together with brookite, has already been recorded as occurring in "a soft yellowish earth" filling joints in the quartzite (O'Reilly, 1898).

Anatase is fairly common in some of the heavy residues. It is always blue in colour, and assumes the form of square plates or of bipyramidal grains. The measurements are usually less than 0·1 mm.

Brookite has not been found in any of the quartzites but it occurs in quartzose slate in the quarries south of Shankill Castle, and is not infrequent in the soils near Carrickgollogan. It occurs as striated brownish plates, which give the characteristic interference figure. The grains range up to about 0·2 mm.

O'Reilly suggested that the titanium dioxide of the anatase and the brookite was derived from rutile. This may be partly true, but ilmenite must be considered as another possible source. Ilmenite was evidently very abundant in the original sediment

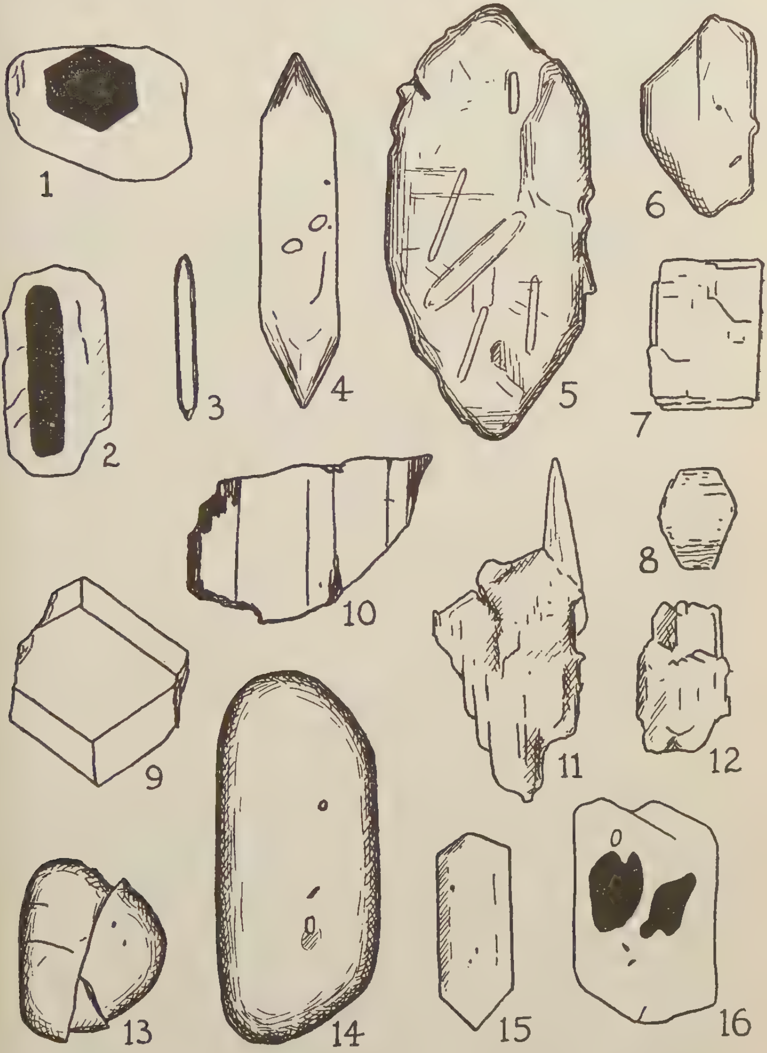

FIG. 2.—Heavy mineral grains.

whilst rutile, even in the least altered rocks, is rare. The ilmenite, it may be supposed, suffered decomposition to form leucoxene, anatase and brookite. It is significant that the analyses given by O'Reilly for the anatase show about 16 per cent of iron. But much of the iron of the ilmenite may have gone to form pyrite. This mineral has not been found in these rocks, but cubes of *limonite*, their faces frequently striated after the manner of pyrite cubes, are abundant in some of the quartzites.

Secondary *epidote* has been found in only one sample of quartzite from Carrickgollogan.

In the following table the heavy mineral suite of the Cambrian rocks around Carrickgollogan is compared with that of the quartzites from the region of the Great Sugar Loaf Mountain near Bray.

	Anatase.	Brookite.	Epidote.	Ilmenite.	Leucoxene.	Limonite.	Rutile.	Tourmaline.	Zircon.
Great Sugar Loaf District .	—	—	—	×	×	—	×	×	×
Carrickgollogan . . .	—	—	×	×	×	—	×	×	×
North-West Area . . .	×	—	—	×	×	×	—	×	×
Shankill Castle Area (Quartzose slate)	×	×	—	—	×	×	—	×	×
Shankill Castle Area (Quartzite)	—	—	—	×	×	—	×	×	×

THE ORDOVICIAN.

The Ordovician sediments of the county of Wicklow consist of " black or dark grey slates, often interstratified with thin dark grey fine grained grits " (*Mem.* 121 and 130, 1869). In the south of Wicklow they become " variously interstratified with rocks of igneous origin, both traps and ashes ".

A little south of the present area, near Enniskerry, greenish tuffs are certainly present, and in the schists of the present area there occur what are undoubtedly the metamorphic derivatives of rocks of igneous origin, probably andesitic in composition.

At Lambay Island and Portraine (Gardiner and Reynolds, 1897, *Quart. Journ. Geol. Soc.*, vol. liii, pp. 520–35) there is definite evidence of volcanic activity, with the extrusion of andesitic lavas and the formation of volcanic ashes, in Bala times. It is reasonable to suppose that this region of vulcanicity may have extended southwards into the south of the county of Dublin and into the county of Wicklow.

The only exposures of unmetamorphosed Ordovician rocks in the Ballycorus district are found along the southern side of Carrickgollogan. When Du Noyer surveyed the area about the year 1860 a road had been newly constructed here and exposures were evidently good. On his manuscript map he records the occurrence of slates of various types, including some with an "ashy look". At present the exposures are poor, but the bluish slates which are seen strongly resemble the Ordovician slates occurring further south.

The passage of unaltered sediments into metamorphic rock is not seen in the present area. Schists are well exposed at the Scalp, at Rathmichael, and on the high ground between Carrickgollogan and Ballycorus, and represent a fairly high grade of metamorphism. The fringe of the metamorphic aureole appears to be concealed in the lowland by drift and on the higher ground by Cambrian rocks which have been thrust over the Ordovician (Cole, 1921).

The following table gives the heavy minerals which have been found in the rocks of the aureole. The rocks are classified according to their facies and not according to locality. Minerals which have been found in only one sample are indicated by the sign I.

	Schists derived from		
	Slates.	Grit Bands.	Volcanic Rocks.
Andalusite . .	×	—	—
Apatite . .	×	I	×
Biotite . .	×	×	×
Cerussite . .	I	—	—
Chlorite . .	×	×	×
Garnet . .	×	×	I
Hornblende . .	—	—	×
Ilmenite . .	×	×	×
Magnetite . .	×	—	—
Pyrite . .	I	—	×
Pyrrhotite . .	—	—	×
Rutile . .	×	—	—
Staurolite . .	×	—	—
Tourmaline . .	×	×	—
Zircon . .	×	×	—

Heavy Minerals of the Mica Schists.

Andalusite occurs in some of the mica-schists, usually within a hundred yards of the granite. Where conditions have been favourable for its formation it has developed in the form of large prisms of a purplish colour, which are very conspicuous; but except in the case of these typical andalusite-mica-schists the mineral is absent from the heavy residues.

Apatite is frequently found in the heavy residues in small amounts and occasionally a few small clear prisms are seen in the thin sections.

Biotite is present in most of the schists and frequently shows alteration to chlorite. The biotite, when heated before the blowpipe, fuses to form a black magnetite globule, and in this respect resembles the haughtonite of the granite.

Cerussite occurs in the schist at Ballycorus and is derived, no doubt, from the alteration of galena in the neighbouring veins.

Garnet can rarely be observed with the naked eye, but its presence in most of the schists is revealed in the thin sections and in the heavy residues. Though usually in the form of round grains, the garnet was found in one of the schists to consist of distinct rhombic dodecahedra, many of the crystals having a platy habit due to the abnormal extension of two opposite faces. The garnets sometimes contain round or irregular inclusions of a black opaque mineral.

Ilmenite is frequently present, sometimes showing alteration to leucoxene.

Magnetite occurs in the andalusite schists.

Pyrite is found only near the metalliferous veins at Ballycorus, where it occurs in the form of small pyritohedra.

Staurolite, though frequently met with in the soils of the region, has been recognized in only two samples of schist. It is pale yellow in colour, shows faint pleochroism and contains dark inclusions similar to those in the garnet.

Tourmaline, in the form of brownish prisms, is very widespread and in some of the schists, especially near the aplite veins and elvan intrusions, is very abundant.

Zircon and *rutile* are both scarce.

METAMORPHOSED GRIT BANDS.

The minerals developed in these rocks are naturally less varied than those of the metamorphosed argillaceous rocks. Where the original structure has not been obliterated these rocks appear to have been rather fine grained sediments, the grains rarely exceeding a quarter of a millimetre. The only heavy mineral which is undoubtedly original is zircon, although garnet, tourmaline and biotite are also found, the latter frequently showing alteration to chlorite.

The garnet usually differs from that of the schists, being in the form of granular aggregates penetrated by quartz, and not in the form of simple grains.

METAMORPHOSED IGNEOUS ROCKS.

The metamorphosed igneous rocks are exposed in only a few places. Near Puck's Castle, Rathmichael, there is a hornblende schist which probably represents a thin sill or lava flow of andesitic composition. The rock consists of laths of pale green hornblende with their interstices filled with granular andesine. The hornblende shows pleochroism from bluish green for light vibrating along the *c* axis to yellowish green for light vibrating at right angles to that direction. Both minerals have inclusions of apatite, which occurs as clusters together with grains of ilmenite. Pyrite and pyrrhotite are found in the heavy residue. A very similar rock is exposed in a roadway about 700 yards south-west of Ballycorus Chimney. Further towards Carrickgollogan another hornblende-schist occurs, associated with what appears to be a metamorphosed tuff. The hornblende-schist contains the same pale green hornblende, but the prisms are distorted and do not extinguish uniformly. The spaces between the hornblende crystals are filled with cryptocrystalline material. The heavy residue contains abundant ilmenite and apatite. The apatite occurs in the form of short prisms—the maximum length being about 0·18 mm.—which frequently have dark cores. These grains, however, differ from those of the granite in that the cores are not pleochroic, and with a high magnification the dark colour seems to be due to innumerable minute opaque inclusions. The metamorphosed tuff contains biotite, chlorite, garnet, plagioclase, pyrrhotite and pyrite.

SUPERFICIAL DEPOSITS.

The examination of the soils of the district serves as a check on the completeness of the heavy mineral separations made with the solid rocks, and it has sometimes happened that a mineral has been found in the soils or sands before it was detected in the rock.

In studying the superficial deposits, however, it is necessary to remember that during the Glacial Period detrital material was imported into the neighbourhood from the north. It was essential, therefore, to examine the glacial drift of the area lying to the north, and thus determine the nature of the imported suite of minerals. The manner in which this northern material contaminates the local soils is rendered obvious, even on a brief inspection, by the abundance of small pebbles of Carboniferous Limestone and black chert even near the hill summits. In the Wicklow Mountains this contamination extends nearly to a height of 2,000 feet, and it is only on such summits as Kippure that one can feel sure that one is dealing with a pure granitic soil.

The following table indicates the heavy minerals present in the superficial deposits :—

	Glacial Deposits.	Sands and Soils Derived from		
		Granite.	Schists.	Quartzite.
Andalusite	×	—	×	×
Anatase	×	×	—	×
Apatite	×	×	×	—
Barytes	—	×	—	—
Brookite	—	—	—	×
Epidote	×	—	—	×
Garnet	×	×	×	×
Hornblende	×	—	×	×
Ilmenite	×	×	×	×
Kyanite	×	—	—	×
Leucoxene	×	×	×	×
Limonite	×	×	—	×
Magnetite	×	×	×	×
Monazite	×	×	—	—
Rutile	×	×	×	×
Spodumene	—	×	—	—
Staurolite	×	×	×	×
Tourmaline	×	×	×	×
Zircon	×	×	×	×

The general results of the examination of the superficial deposits suggest that the list of minerals of the granite is now fairly complete, but that some of the scarcer minerals, such as rutile, are more widespread than the examination of the granite has indicated. The scarcity of brookite is confirmed by its absence from the soils except upon the quartzite. The absence of sphene from the granite and superficial deposits is of interest, since the Geological Survey Memoir to Sheet 112 records this mineral as one of doubtful occurrence in the granite.

The presence of kyanite in some of the soils cannot be taken as evidence of the occurrence of this mineral in the schists of this area, as kyanite is one of the suite of minerals imported into the district during the Glacial Period.

The writer wishes to express his indebtedness to Mr. G. M. Davies for help and encouragement in the course of this research ; and to the Governors of Birkbeck College, London, for the award of a Research Studentship.

KEY TO FIG. 2.

		Magnification.	*Source.*
1.	Apatite	163	Xenolithic rock (?), South of Kippure.
2.	,,	163	Granite, The Scalp.
3.	Zircon	181	,, ,,
4.	,,	181	Muscovite, Kippure.
5.	Monazite	184	Granite, The Scalp.
6.	,,	184	,, Lough Bray Upper.
7.	Anatase	156	Muscovite, Kippure.
8.	,,	156	Granite, ,,

		Magnification.	*Source.*
9.	Garnet . .	174	Schist, The Scalp.
10.	Brookite .	156	Quartzose Slate, Shankill.
11.	Spodumene .	163	Sand, Carrickmines Golf Course.
12.	,, .	163	,, ,, ,,
13.	Zircon . .	174	Quartzite, near Carrickgollogan.
14.	,, (Purple)	163	,, north-west of Carrickgollogan.
15.	Tourmaline .	163	Schist, Ballycorus.
16.	,, . .	163	,, ,,

BIBLIOGRAPHY.

1869. *Geological Survey Memoir to Sheets* 121 *and* 130.

1889. Sollas, W. J. "Contributions to a Knowledge of the Granites of Leinster": *Trans. Roy. Irish Acad.*, vol. xxix, pp. 427–514.

1892. —— "On the Structure and Origin of the Quartzite Rocks in the Neighbourhood of Dublin": *Sci. Proc. Roy. Dublin Soc.*, vol. vii, p. 169.

1898. O'Reilly, J. P. "On the Occurrence of Anatase and Brookite in the Quartzites of Shankill": *Sci. Proc. Roy. Dublin Soc.*, vol. viii, p. 732.

1903. *Geological Survey Memoir to Sheet* 112. (Contains a very full bibliography.)

1908. *Handbook to Dublin and the Surrounding District.* (British Association.)
Cole, G. A. J. Geology.
Kilroe, J. R. Glacial Deposits.
Seymour, H. J. Mineralogy.

1912. Ryan, W. J., and Hallissy, T. "Preliminary Notice of some New Fossils from Bray Head, County Wicklow": *Proc. Roy. Irish Acad.*, vol. xxix*b*, pp. 246–51.

1921. Cole, G. A. J. "The Problem of the Bray Series": *Proc. Roy. Irish Acad.*, vol. xxxvi*b*, pp. 1–10.

1922. Smyth, L. B. "On a Variety of Pinite occurring at Ballycorus, County Dublin": *Sci. Proc. Roy. Dublin Soc.*, vol. xvi (N.S.), p. 492.

1926. Farrington, A. "Topographical Features of the Granite-Schist Junction of the Leinster Chain": *Proc. Roy. Irish Acad.*, vol. xxxvii*b*.

A Supposed Implement of Quartzite from beneath the Boulder Clay of the Durham Coast.

By C. T. Trechmann, D.Sc., F.G.S.

(PLATE III.)

HAVING always been much interested in any evidence that might throw light on the relationship of early man to the glacial drifts, I have for twenty-five years or more watched the various beds of gravel that occur above, among, and below the Boulder Clays in the north-eastern counties for anything resembling a Palaeolithic implement. I had no approach to success, however, till about a year ago, when in a bed of water-deposited gravel at a place called Limekiln Gill on the Durham coast, between the entrance of Hesleden Dene and Blackhall Rocks, some 4 miles north-west of Hartlepool, I found in the gravel cliff about 4 feet above the level of the beach a piece of yellow quartzite, which seemed to be artificially chipped. A short while ago I sent the specimen to Mr. Reginald A. Smith, B.A., F.S.A., of the British Museum, for his opinion, and somewhat to my surprise received the following reply: "I have little doubt about your implement, and Mr. Reid Moir, who saw it yesterday, agrees that it is definitely human. It is, indeed, interesting to find such a thing in situ, and one might expect to find it in some margin between the two principal boulder clays (Interglacial of East Anglia)." Such being the opinion of these experts, the specimen becomes one of very considerable significance, since the bed in which it was found underlies the main Cheviot and Northern drift or Purple clay, which at this spot is at least 70 feet thick and consists very largely of typical boulder clay.

The specimen measures 3½ in. (89 mm.) in length, 3 in. (76 mm.) in width, and is 1½ in. in thickness. It consists of yellow translucent faintly banded quartzite, and is roughly chipped, with part of the smooth crust of a water-worn pebble remaining on one side. Six distinct and definite chips can be traced on one side, and an equal number on the other, and there are traces of about three other blows which have left cracks but failed to detach flakes. All the chips appear to be of one period, and since the chipping the specimen has been considerably rolled, and its edges have been rounded. If it is an implement it is apparently a somewhat rough attempt to make a hand axe of Chelles or St. Acheul type, and it seems to show a definite attempt to produce a point and a butt. I cannot help thinking that if it were of flint and had been found in a recognized implement-

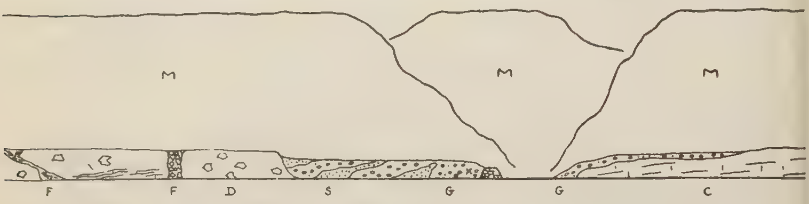

Fig. 1.—Diagram of part of the Durham Coast at Limekiln Gill, one mile south of Blackhall Rocks, showing the mode of occurrence of water deposited sands and gravels beneath the Boulder Clay. C, Concretionary Magnesian Limestone slightly disturbed. D, Soft yellow dolomite, much disturbed, enclosing angular masses of soft fetid and concretionary limestone. F, Fissures filled with angular masses of soft fetid and concretionary dolomite; near the base of one of them are small glaciated fragments of crystalline rocks. These disturbances in the Magnesian Limestone were caused by the early oncoming of the Scandinavian glaciation. S.G, Current bedded sand and gravel containing Scottish, Cheviot, Lake District, and local stones. The quartzite specimen was found at X. A few feet of brown sand overlie the gravel. M.M, Main Cheviot and Northern drift of the Durham Coast about 75 feet thick. This and the gravel bed underlying it are cut through by a post-glacial ravine at the entrance of which there is an old limekiln.

bearing deposit, it would pass without question as a rough implement.

POSITION OF THE GRAVEL BED.

I have already published two papers[1] dealing with the Durham glacial deposits, in which this and other similarly situated sub-boulder clay gravel beds are described in some detail. The Limekiln Gill gravel bed occupies a depression or wash-out of the Magnesian Limestone, and extends over a length of about 100 feet and seems to be about 12 feet thick. It is made up of a varied assortment of stones; small fragments of gneiss, mica-schist, grey and black garnetiferous and hornblende-schists are not uncommon, but no trace of typical Norwegian rocks has been found. Conglomerates and grits from the Silurian beds of the Lowlands of Scotland, together with granites, diorites, and quartz and quartzite pebbles also occur. Olivine-basalts, Cheviot andesites, porphyrites, carnelian, and various Lake District rocks are present. The more local material comprises fragments of Carboniferous limestone, including the Saccammina band, Magnesian Limestone of various kinds, and numerous specimens from the Coal Measures. Bits of worn and irregularly shaped flint of various colours together with fragments of chalk are found. Marine shells include occasional hinges of *Cyprina islandica, Astarte* and small fragments of shell meal (Scandinavian Drift paper, p. 68; Loess paper, p. 191.) A similarly situated but more extensive gravel and sandy bed occupies a depression in the Magnesian Limestone near Horden Point, about 3½ miles north-west of Limekiln Gill. It attains a depth of about 40 feet and underlies about 80 feet of sandy and stony boulder clay, but has yielded nothing with any appearance of artificial chipping.

Another water-deposited bed underlying boulder clay, analogous in character to the last two, occurs at Horsebridge Head, on the Northumberland coast, about ½ mile north of the mouth of the River Wansbeck. It occupies a depression of the Coal Measures, and is protected on the north by a low cliff of shale. It has been examined and described by Dr. J. A. Smythe,[2] the late Dr. D. Woolacott,[3] and myself (Scandinavian Drift paper, p. 68).

At Beacon Hill, to the north of Easington and about 9 miles north-west of Hartlepool, a remnant of deposit which is admitted by all who have seen it to be a fragment of a beach, occurs at an altitude of 60 feet in a wave-worn depression of the Magnesian Limestone.

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[1] "The Scandinavian Drift of the Durham Coast and General Glaciology of South-east Durham," *Q.J.G.S.*, vol. lxxi, 1915, pp. 53–82, and pl. viii. "On a Deposit of Interglacial Loess and some Transported Preglacial Freshwater Clays on the Durham Coast," *Q.J.G.S.*, vol. lxxv, pt. 3, 1919, pp. 173–203.

[2] "The Glacial Geology of Northumberland," *Trans. Nat. Hist. Soc. of Northumberland and Durham*, New Series, vol. iv, 1912, p. 98.

[3] "The Superficial Deposits and Pre-glacial Valleys of the Northumberland and Durham Coalfield," *Q.J.G.S.*, vol. lxi, No. 241, 1905, p. 68.

It has yielded about eleven species of shells of types at present common on the coast, bored fragments of Magnesian Limestone and rounded pieces of rock from the Cheviots and the Lake District. It is covered by a layer of calcreted gravel, which tails off southwards into boulder clay, and is overlain by about 20 feet of material which seems to me to be typical glacial boulder clay. Dr. Woolacott described it as a post-glacial beach[1] while the late Mr. G. W. Lamplugh, after he had seen it, told me that he considered it pre-glacial. However, the evidence seems to force one to the conclusion that both this beach fragment and the sub-boulder clay gravels at Limekiln Gill, Horden Point, and Horsebridge Head, though not necessarily all contemporaneous, are the products of a mild interval that occurred shortly after the oncoming of the northern glaciation which brought down the northern erratics and later deposited the main mass of the boulder clay of the Durham coast. All these gravel beds certainly indicate a period when the Scottish, Lake District, Cheviot, and other northern stones had already arrived on the Durham and Northumberland coasts.

All the deposits already mentioned overlie and are very clearly later than the relics of the Scandinavian glaciation. The effects of the Scandinavian ice or ice-sheet are much more closely associated with the underlying Magnesian Limestone formation than with the overlying English and Scottish drifts. At a locality called Warren House Gill on the Durham coast the grey slickensided basement clay with Arctic shells and Norwegian stones (but no trace of North English or Scottish erratics) has been forced into a fissure and depression, and is partly overlain by loess-like material. At various points along the coast to the north and south for several miles fissures occur rammed tight with red and green marl which contained in one instance some very interesting plant and seed-bearing clays, together with a vertebra and other bones of an elephant (Loess paper, p. 201). All these deposits connected with the Scandinavian drift end abruptly at the top of the Magnesian Limestone cliffs, the irregular surface of which was planed off later by the combined Scottish and Lake District ice-sheets. However, depressions are found here and there, some of which seem to have been eroded after the retreat of the Scandinavian ice; for example, the wash-out at Limekiln Gill and the raised beach at Easington. A third type of boulder clay was revealed by dock excavations at Hartlepool, where it occupies a deep depression between two outcrops of Magnesian Limestone (Scandinavian Drift paper, p. 77). The erratics in it were of westerly and north-westerly origin, and included many that must have come from Westmorland and the Lake District over the Stainmoor Pass. Though I found no Shap granite erratics in the excavation, this bed of clay seems to have been carried by the same westerly ice-sheet or lobe that transported them, to South Durham and Yorkshire.

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[1] Geol. Mag., Vol. LIX, No. 692, February, 1922, p. 64.

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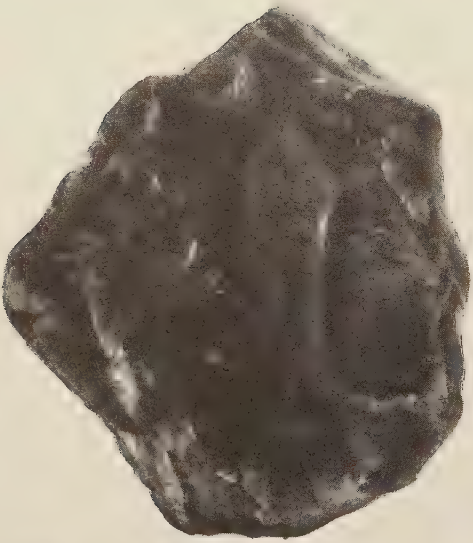

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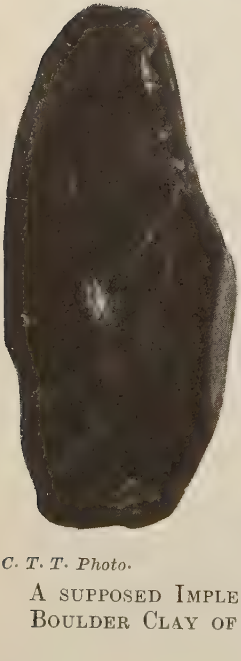

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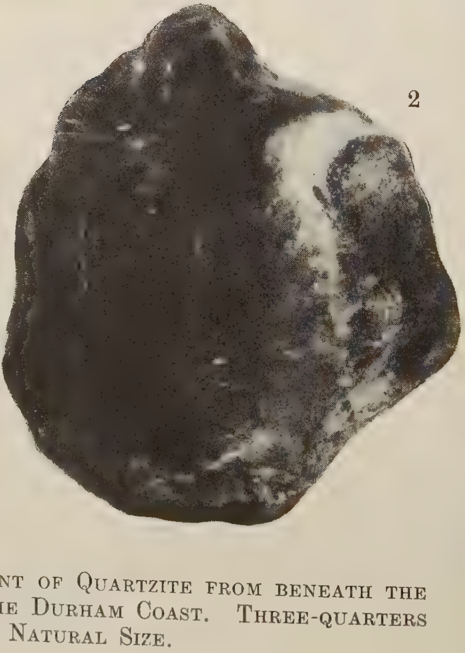

C. T. T. Photo.

A supposed Implement of Quartzite from beneath the Boulder Clay of the Durham Coast. Three-quarters Natural Size.

To face p. 29.]

The Limekiln Gill gravel, where the supposed implement occurred, is therefore later than the Scandinavian glaciation of the Durham coast, and later than the westerly or Stainmoor boulder clay of Hartlepool, but earlier than the Cheviot and Scottish drift which forms the main mass of the boulder drift that caps the coastal cliffs.

REMARKS.

In view of the fact that the northern rivers, such as the Tyne, Wear, and Tees, seem to have no old terraced gravels comparable with those of the southern rivers, I used to suppose that the probable position for Palaeoliths, should they occur in the north, would be among the kaims or gravel spreads above the boulder clay. If the present specimen be an implement it would seem to indicate that relics of Chelles or St. Acheul times should be looked for beneath the later boulder clays. This would give point to a remark which the late Mr. Lamplugh once made to me to the effect that only the periodical melting or release of great masses of ice to the north could have given rise to the river and plateau gravels and contorted drifts of the southern districts.

At least, one may surmise that the absence or extreme rarity of palaeolithic implements in the northern districts is due to the twofold fact that flint in large pieces being absent, other less easily workable stones had to be used ; and that early man (or stone-chipping Hominid) did not find the north a very agreeable abode even during the milder lapses which appear to have occurred during the glacial period.

EXPLANATION OF PLATE III.

Supposed Palaeolithic implement of bright yellow Quartzite from a gravel bed beneath the main Boulder Clay at Warren House Gill, on the Durham Coast. About three-quarters natural size. Fig. 1 : Side with crust entirely chipped away. Fig. 2 : Side with part of crust of pebble remaining at right hand. Fig. 3 : Edge view.

A Monticellite-Nepheline-Basalt from Tasmania: a correction to mineral data.

By C. E. TILLEY.

F. P. PAUL described in 1906 (*T.M.P.M.*, vol. 25, p. 309) a nepheline-eudialite-basalt from Shannon Tier, Tasmania, containing an unknown mineral referred by him to Ca_2SiO_4. Subsequently Bowen (*Amer. J. Sci.*, 1922, p. 30) pointed out the close correspondence between the optical properties of Paul's mineral and of the artificial β-Ca_2SiO_4 prepared by Day, Shepherd and Wright. Still later (GEOL. MAG., 1927, p. 43) the writer of this note ventured to apply the name shannonite to the mineral of this singular occurrence. Since that time through the kindness of Mr. P. B. Nye, Government Geologist of Tasmania, a specimen of the rock described by Paul from Shannon Tier has been obtained and examined. That the specimen examined is identical with the rock described by Paul is clearly indicated by his detailed description and the photomicrograph which accompanies his paper. Unfortunately my own determinations are not in agreement with those of Paul, and the purpose of the present note is to state the nature of these discrepancies. The rock is a felspar-free nepheline-basalt of which the chief constituents are idiomorphic nepheline, a titaniferous augite, olivine (chrysolite), the unknown mineral of Paul, biotite, apatite, magnetite, perofskite, and minor amounts of interstitial analcime. The described eudialite has not been discovered, and from the description attached to the photomicrograph this mineral appears to have been confused with nepheline. I find further that the properties of the unknown mineral agree, not with those of any of the artificial calcium orthosilicates, but with those of monticellite. The two olivines are readily distinguished in thin section, the chrysolite occurring as chadacrysts and the monticellite as oikocrysts, the latter appearing as shapeless grains often surrounding chrysolite and enclosing numerous idiomorphic crystals of nepheline and magnetite, and thus belonging to a late stage in the crystallization history of the rock. The chrysolite moreover is readily distinguished —apart from these textural differences—by its higher birefringence and larger optic axial angle (near 90°).

The refractive indices of Paul's mineral lie between 1·66 and 1·68, much below the values 1·718 to 1·740, indirectly arrived at by Paul. The mineral is optically negative (not positive as stated by Paul), and possesses a considerably lower optic axial angle than chrysolite, sections normal to the optic axis showing a marked curvature of the isogyre. (Using Paul's value of E and β as 1·67, $2V = 67°$, while monticellite from Isle Cadieux has $2V = 70° \pm 5°$.) It may be convenient to restate Heidenreich's analysis of the rock as follows: SiO_2 36·03, Al_2O_3 15·19, Fe_2O_3 5·94, FeO 9·55, MgO 8·60, CaO 15·52, Na_2O 4·23, K_2O 1·85, H_2O (ignition) 0·58, P_2O_5 1·38, TiO_2 1·13, MnO 0·17, ZrO_2 0·21.

This analysis corresponds fairly closely with that of a melilite-nepheline-basalt from Sebusein, Bohemian Mittelgebirge. From the analysis and the further data provided by Paul the Tasmanian rock has the mineral composition approximately—nepheline 27%, Augite 27%, monticellite 27%, chrysolite 14%.

It is necessary to conclude that calcium orthosilicate does not occur in this Tasmanian rock, nor in any igneous rock yet described. The mineral is monticellite and the name shannonite—given from Paul's data—must therefore be withdrawn. I have indicated elsewhere the occurrence of calcium orthosilicate as an abundant constituent of certain contact limestones, but a detailed description of this occurrence has yet to appear.

REVIEWS.

RELATIONS OF METALLIFEROUS LODE SYSTEMS TO IGNEOUS INTRUSIVES. By W. H. EMMONS. *Trans. Amer. Inst. Min. Met. Eng.*, vol. lxxiv, 1926, pp. 29–70.

MAGMAS, DIKES AND VEINS. By WALDEMAR LINDGREN. Ibid., pp. 71–126.

THE two papers quoted above, which were read and discussed at the New York meeting of the American Institute of Mining and Metallurgical Engineers, must be considered as marking an important stage in the perennial subject of the origin of ore-deposits and their relation to igneous magmas. The first-named, by W. H. Emmons, deals mainly with the relation of ore-deposits to batholithic intrusions, especially with regard to spatial relationships. It is assumed as axiomatic that by far the greater number of ores are either magmatic segregations, which are igneous rocks in the true sense, or veins and deposits formed by solutions originating in intrusions. Those deposited by meteoric waters are considered to be of very minor importance. First of all it is shown that ores tend to be concentrated in and around the irregular upper surfaces of batholiths, and the vast majority in and around rocks more acid than diorite, with a definite relationship to cupolas and roof-pendants. Furthermore it is shown that the different metals extend downwards to different degrees in the batholiths. This leads on to a detailed discussion of the now well-known zonary succession of the metals. This section is illustrated by numerous maps and descriptions of prominent mining areas, mostly American, but including Cornwall, which the author has recently visited. We venture to quote part of his remarks on this area, which should be particularly pleasing to the British geologists interested in the subject: "This is a classic area for the study of successive zones: it was here that they were first recognized and prospecting was carried on with the standard changes in mind . . . Because of the number of intrusives and the variety of metals present, Cornwall is probably the most instructive area known for the study of zones." The literature is very fully cited. The general conclusion from the study of all the areas examined is that the generalized zone-succession, as outlined by Spurr twenty years ago and amplified by later writers, is now fully established, although of course there are occasional exceptions. This subject is again referred to by Spurr in the discussion on Lindgren's paper. For details as to the relation of ore-deposits to varying depths of erosion in the parent batholith the original paper should be consulted: they cannot fail to be of value, but space will not allow of their reproduction here.

The second paper cited, by Professor Lindgren, is in fact very largely devoted to an exposition and criticism of Spurr's conception of "ore-magmas" and "veindikes", that is, the intrusion of vein-fillings as a viscous magmatic mass, which forces open the fissures and fills them with ore and gangue in one single spectacular process. A great deal of this discussion, here and elsewhere, hinges on the occurrence of "unsupported inclusions" in brecciated veins. Apparently what is needed here is an application of the method of serial sections to such vein-fillings, in order to ascertain whether the fragments really are isolated in the vein-filling, or whether they do possess points of mutual support. The term "ore-magma" is examined and rejected, except for special cases, e.g. a normal magma rich in sulphides and oxides or certain pegmatite dykes rich in metals. Also, much importance is attached to contact metamorphism and replacement (pyrometasomatism) as a universal phenomenon attending the solidification of magmas. The principle of zonary succession is also the subject of some severe criticism. The author expresses considerable scepticism as to whether a true pegmatite dyke has ever been traced laterally into a true quartz-vein. This is perhaps to some extent a matter of terminology, but few British mining geologists would probably be found to support him on the general principle.

This paper was followed by an animated discussion, which in the printed report is closed by a long written communication from Mr. Spurr, restating and clarifying his position, together with the author's reply.

The whole of this episode is most refreshing to those British geologists who for years past have been trying to obtain a clear view as to what is meant by the "magmatic origin of ore-deposits". It can scarcely be denied that on this side of the Atlantic there has been a great deal of confused thinking on the subject, and the present writer does not feel his conscience altogether clear in this respect. The crux of the matter is, what do we really mean by the words "magmatic" and "hydrothermal" respectively? If the term magmatic is taken in the narrowest sense, to indicate those ore-deposits which are themselves primary intrusive igneous masses, it must be admitted that there are not very many of them, though perhaps more than are allowed by Professor Gregory, for example. But there can be no doubt that ore-bearing solutions of direct magmatic origin, residuals containing volatile constituents at comparatively low temperature, have contributed very largely to the formation of deposits of the common metals, such as gold, copper, zinc, lead and silver; even antimony and mercury; how otherwise are we to account for the common association of such metals with igneous activity in all its forms? What is needed now is an authoritative decision whether ores thus formed are or are not magmatic. If this point were once settled the situation would be much clearer: at present it is to be feared that much confusion has arisen from different interpretations of the meaning of terms.

R. H. R.

LEACHED COPPER OUTCROPS AS GUIDES TO COPPER ORE. By AUGUSTUS LOCKE. pp. vii + 175, with 24 plates and 18 text-figs. London: Baillière, Tindall and Cox, 1926. Price 22*s.* 6*d.*

IT is well known to all economic geologists that primary copper-sulphide deposits undergo a marked degree of alteration in the zone of oxidation, resulting often in complete removal of the copper down to a very considerable depth, with separation and precipitation on the spot of various compounds of iron. The task that the author of this book and his collaborators set themselves was to determine whether it was possible to ascertain from the leached and weathered residual rock what was the original character and value of the sulphide ore before alteration, and what prospect there may be of the existence of workable ores below. The principle will be best understood from the following slightly shortened quotation: "The quantity of iron in certain ores remains the same during oxidation, and the iron-copper ratio in the sulphide is in some degree determinable from the evidences afforded by the capping, partly through studies of transitions away from the capping under investigation and partly through experimental studies of the equilibrium-relations in the systems involved." In some cases quantitative estimates have been obtained, as it is found that the resulting iron precipitates vary in character according to the amount of copper originally present. Most of the different products of oxidation of the iron are as a rule included in the general term "limonite", but of course this is not a true mineral species, being in reality a colloform aggregate of very variable water content and variable structure, form and colour. The work was mainly carried out in the south-western United States, and it gives promise of considerable value as a development in scientific prospecting, opening up a wide field of research in weathered and oxidized rocks, a subject which has been hitherto much neglected, especially in this country, though its value is more appreciated in America.

R. H. R.

THE COUNTRY BETWEEN STAFFORD AND MARKET DRAYTON. Mem. Geol. Surv. Eng., Expl. of Sheet 139. By T. H. WHITEHEAD, E. E. L. DIXON, R. W. POCOCK, T. ROBERTSON, and T. C. CANTRILL. xiii + 128 pp., 5 plates, 5 text-figures. Price 3*s.* 6*d.* net.

THIS volume describes the geology of an agricultural part of Staffordshire and Shropshire. The solid formations are represented by small tracts of Carboniferous Limestone and Middle Coal-Measures, and larger areas of Upper Red Coal-Measures on the western margin of the map; by Bunter and Lower Keuper on both the eastern and western margins; and by a large expanse of Keuper Marl which occupies the greater part of a central fault-trough of Malvernian trend.

The Upper Coal-Measures rest unconformably on the older Carboniferous, and include the Keele Series and probably the base of the Calcareous Conglomerate group. The Enville breccias, however, are absent, and so no further progress is made towards a universally accepted classification of these perplexing beds.

A rather unusual point of interest is provided by the discovery of large silicified logs of the Staffordian plant *Dadoxylon kayi* Arber, in the Bunter pebble-beds. From the large size of these pieces compared with the pebbles, the Survey Officers are forced to the conclusion that the wood was derived from the Upper Coal-Measures, and incorporated in the Bunter, whilst still only, at most, slightly silicified. Subsequent change then gave the present state of preservation.

Glacial deposits are important, and are treated in a highly interesting chapter. This discusses the causes and effects of the glacially dammed lakes, Newport, Buildwas, and Lapworth, which were described by Dr. Wills in 1924; and also records a number of esker ridges formed as the ice front retreated, these eskers being crossed at intervals by outwash fans which indicate temporary pauses in the ice-recession. Post-glacial deposits receive but brief mention, and although river terraces are present, no fossils or artifacts have been found, to give them more than a local significance.

The volume also includes a description of the well-known Swynnerton-Butterton basanite dyke, and concludes with the usual chapter on water supply and mineral resources. The latter, as might be expected in an agricultural country, are not of great importance.

F. W. S.

COAL IN GREAT BRITAIN. By WALCOT GIBSON. Second edition. pp. vii + 334, with 8 plates and 53 text-figures. London: Edward Arnold and Co. Price 21*s*.

IN this new edition, besides minor corrections, the chapters dealing with North Staffs, Yorks and Notts have been brought up to date, and the section dealing with Scotland is rewritten. The most important addition is a new chapter on the origin and characters of the British coalfields. This will be read with much interest. It might perhaps be wished that the author had let himself go a little more in his treatment of concealed and unproved fields and their tectonic relationships, since some of his remarks and allusions are rather tantalizing.

We should like to point out one small error, perpetuated from the first edition: the Dent and Craven faults are not synonymous, as implied on page 260, but quite separate dislocations. The last-named is the one here intended, as forming the north-east limit to the Ingleton coalfield.

CHEMISCHE GEOLOGIE. By F. BEHREND and G. BERG. pp. x + 595, with 61 text-figures. Stuttgart: Ferdinand Enke, 1927. Price M.38, in paper covers: M.45·40 bound.

IN the first place the reviewer wishes to make it perfectly clear that he has read very nearly the whole of this book; no light task, as it runs to 595 pages; and that it contains a very large amount of extremely valuable material, ably and clearly presented, which cannot fail to be of the greatest help to those interested in the chemical side of geology. If the rest of this review appears to be mainly adverse criticism, these facts must be taken into due consideration. It is always difficult to preserve a due balance between appreciation and fault-finding.

The first point that presents itself is that the book is much longer than it need have been, owing to a very wide interpretation of the word "chemical". For example, 35 pages on mechanical weathering and 18 pages on mechanical sedimentation are distinctly outside of the avowed scope of the work, and might with advantage have been omitted. Neither of these sections contain anything which can fitly be regarded as chemistry.

To turn now to matters of detail: the account of the system Al_2O_3–SiO_2 reproduces the old diagram which is said by the workers at the Carnegie Institute to be out of date: the later work on mullite is not mentioned. Whether this is substantiated or not, it should have been included. It is now generally recognized that there is no mineral limonite with a definite composition, as assumed on p. 370. On p. 374, referring to the solubility of silver chloride in the presence of alkaline chlorides, the author seems to contradict himself in two consecutive sentences.

The section on oolitic iron ores is particularly unsatisfactory. A reference is given to the two splendid volumes by Professor Cayeux on the iron ores of France, but the author has obviously not read the second volume, since he states that in the opinion of Professor Cayeux the oolitic ores of Lorraine and Cleveland have been formed by metasomatic replacement of limestones. This is simply a travesty of the facts. On page 468 under the heading "phosphates" the second sentence is quite unintelligible. (Incidentally it may be mentioned that the proof-correcting is not good: there are many obvious mis-spellings of words.) The account of the origin of kelyphitic borders on page 512 takes no account of recent results on the incongruent melting-point of enstatite. The equation in the middle of page 519, representing serpentinization, does not add up to the same on both sides: the concomitant removal of magnesia is ignored. Kyanite does not invert to andalusite under pressure, as stated on page 529: quite the reverse.

But all these things are matters of detail, and of minor importance. The really significant feature of this book is the light that it throws on the outlook of its writers on geological science, and presumably also that of their countrymen in general. A study of the index of authors cited is particularly illuminating in this regard. It would appear from this that chemical geology is almost entirely a German science, with a slight sprinkling of American and a trace of Norwegian influence. In a list of about 450 authors quoted there are only about 20 English names, with a few from the British Dominions overseas. In the petrological sections in particular the omissions are glaring. A lengthy discussion of magmatic differentiation without any mention of the names of Teall and Harker may not unfairly be compared to a treatise on the Exodus with no reference to Moses and Aaron. Although there is a discussion of petrographical provinces, J. Jüdd (*sic*) appears in the index only in connexion with the atoll of Funafuti. And so on indefinitely. Now this kind of thing does not help on the cause of science. It only causes unnecessary irritation, and hinders the appreciation in this country of the valuable work which has been and is being done byGerman geologists.

R. H. R.

APES AND MEN. By H. PEAKE and H. J. FLEURE. Clarendon Press, 1927. Price 5*s*.

HUNTERS AND ARTISTS. By H. PEAKE and H. J. FLEURE. Clarendon Press, 1927. Price 5*s*.

PEASANTS AND POTTERS. By H. PEAKE and H. J. FLEURE. Clarendon Press, 1927. Price 5*s*.

PRIESTS AND KINGS. By H. PEAKE and H. J. FLEURE. Clarendon Press, 1927. Price 5*s*.

IT is rare to find in handbooks of this size and price that the author or authors are in the front rank of prehistorians. As a rule smaller and more popular books dealing with the earliest history of mankind are left to the " scissors and paste " men, who though they often do their work exceedingly well, cannot claim authority in their pronouncements. Further, there are far fewer small errors in fact than are usually found in mere compilations from other works.

The first volume opens with a search for the origin of man in connexion with a brief account of the geological history of the earth. The Great Ice Age comes next under review. The multi-glacial theory is accepted and Penck's system adopted, including the post-glacial minor oscillations—Achen, Bühl, etc. Although so unpopular among many pre-historians it might, perhaps, have been well to have mentioned Bayer's two-fold glacial theory, more especially as English geologists never have been happy in accepting a four-fold system of glaciation, though in some cases they have been prepared to accept the evidence for a distinctly warmer interval between two glacial maxima.

This discussion leads naturally to a description of the earlier manifestations of mankind. This portion is perhaps rather too condensed; one would have welcomed, especially for English readers, a considerably longer account of the Tertiary, Middle Palaeolithic and Mousterian cultures. The industries of the Cromer Forest Bed, too, are dismissed in two or three sentences and mentioned in the same paragraph as the Tertiary Eoliths of East Anglia. The industries of the Cromer Forest Bed, however, are exceedingly important from several points of view and are very different in date from their Tertiary predecessors. However, this is only the inevitable result of any attempt to condense an enormous subject into a short space.

The next volume starts with the end of the Great Ice Age and discusses the climate and cultures of Upper Palaeolithic times. Particularly happy perhaps is the account of the art of this time, which is briefly but clearly given and well illustrated.

Thereafter follow chapters sketching what is usuallyincluded in the Mesolithic period but is here named Palaeolithic survivals. The concluding chapter is a chronological summary. Here it may be noted that a very short chronology is accepted and the authors place the Aurignacian culture as late as 11000 B.C. This is a new departure; very few previous authorities have ventured to suggest so recent a date. In some ways, perhaps, this is the best volume of the four and the illustrations are carefully chosen and particularly helpful.

In the volumes *Peasants and Potters* and *Priests and Kings* the authors enter a new realm of study far more difficult to condense while continuing to give a clear and consistent picture of the whole. To a certain extent in the earlier volumes a chronological scheme has been followed, but now this has to be largely abandoned and descriptions given, based on geographical considerations, though at the same time the inter-relationships of the cultures of these geographical areas have to be clearly brought out; especially, of course, is this so in the case of the cultures of the eastern Mediterranean area, which have played such an important part in the development of western civilization as we know it to-day. It is perhaps doubtful whether any better results could have been attained, but at the same time it must be admitted that to a certain extent it makes rather scrappy reading. One thing it will do, however, and that is to stimulate the reader to delve more deeply into this part of the subject, and for this purpose the bibliographies given at the end of each chapter will prove very useful.

In *Peasants and Potters* a short chapter is devoted to the food collectors of the north-west of Europe. In some ways, perhaps, it might have been better if this chapter had been included in the previous volume. It is now more usual to consider together all those cultures which occur from the end of Upper Palaeolithic times to before the introduction of the true Neolithic civilization. Although the Kitchen Midden culture was different from that of Maglemose, there are links between them, and the manner of life and the climatic conditions were not very dissimilar.

There follow accounts of the "fertile crescent" south of the Anatolian Hills and the Nile valley, and a survey of the potter's art. Mesopotamia, the Aegean Isles and the area east of the Caspian Sea next pass under review. The discoveries at Anau in Russian Turkestan are critically considered and once more it becomes obvious that, as soon as political considerations allow, it is imperative to continue excavation work in this district. The authors, following Frankfort, believe that the potter's art reached Anau from somewhere in Anatolia. This, perhaps, may be so, but the reverse may equally be the case. Probably the sands of the deserts of Central Asia, fertile at the end of Quaternary times, have preserved for us some surprises. It may yet be that that vast area was an important cradle of one of our major civilizations.

In *Priests and Kings* the discovery of metal and systems of chronology are described and we are introduced to the early cultures of Mesopotamia and those of the Old Kingdom of Egypt. Later still there follows an account of the Danubian culture of Central Europe. The authors are doubtless right in giving here an account of these people, but it certainly comes as a shock to find that the Danubians —the introducers of so much of our Neolithic civilization into western Europe, where the inhabitants were still living in the simplicity of Mesolithic cultures—have to be considered logically almost at the end of the story! The work concludes with a chronological summary and a brief account of the races of the world.

Again the authors must be congratulated on a really noteworthy addition to the Textbooks on Prehistory and Protohistory. In such a work of condensation it is easy to criticize a lack of balance here and there; but this critic, at any rate, knows full well the difficulties that arise in this connexion, when such a work is undertaken.

M. C. BURKITT.

THE GEOLOGY OF IPSWICH.

THE GEOLOGY OF THE COUNTRY AROUND IPSWICH. By P. G. H. BOSWELL. *Mem. Geol. Surv. England*, Explanation of Sheet 207. pp. x + 121, with 4 plates. Published by H.M. Stationery Office, 1927. Price 3*s*. 6*d*. net.

IPSWICH is an area of special interest from its geology and prehistoric archaeology, and its chief features are described in a scholarly memoir by Professor Boswell. The beds of most interest in the district are exposed in sections which vary rapidly and often had but a short existence. The preparation of the Memoir was therefore wisely entrusted to one who, by residence in the district, had full opportunity of watching the development of the sections through a course of years.

The special feature in this memoir is the lithology of the sediments, a subject the author has made especially his own. He shows, without definitely asserting in which direction the materials have actually come, that the rarer minerals indicate the introduction of the Eocene sediments by a river from the south-west of England, of the boxstones and the Crags from Belgium and the Ardennes, while the source of the Lenham bed material, which is of a very different character, is still unknown. This source of the Crag material is consistent with the existence of a low watershed separating the Thames and Rhine, as recently suggested in the *Geographical Journal.* The Crag includes some material from Yorkshire, so that it appears at first natural to attribute the Rhaxella chert found in the Crag by Mr. Double as from the Yorkshire occurrence; but as Professor Boswell's list of Crag stones includes pebbles from the Bunter of the Midlands and other western rocks, the Rhaxella may have reached the Crag sea from the southern Midlands. Professor Boswell's conclusions as to the origin of the Kainozoic materials are consistent with the history of the river system, which is carefully described and shown to be of pre-glacial age and to have been probably initiated in the Miocene. The much controverted Sarsen stones, Professor Boswell attributes to the Reading Beds.

In description of the glacial deposits Professor Boswell accepts Mr. Harmer's conclusion that the boulder clay to the north of Ipswich is rich in Kimmeridge clay material, while in that to the south-west the predominant inclusions are Oxfordian. He does not accept the existence of two boulder clays in the Ipswich district, and therefore rejects the term Middle Boulder Clay and Middle Glacial Drifts as meaningless in that area. He describes many of the remarkable contortions in the glacial drifts, adopting in general the interpretation give by Mr. Slater; the contortions in the loam under the boulder clay at Haskerton figured on p. 57 appear however much what would be expected from the stranding of floating ice.

The reader naturally turns with special interest to the author's conclusions as to the pre-Paleolithic implements discovered by Mr. Moir, and as to the relation of the paleoliths to the boulder clays. He shows that the balance of opinion is in favour of the human workmanship of the Pliocene flaked stones; but he does not express his own conclusion on the matter. Similarly with the flaked stones found in the Chalky Boulder Clay, he remarks that the human origin of the flaking is not accepted by some archaeologists. The section at the much controverted Foxhall Road brickfield is described in detail (cf. pp. 57, 85); the implements are referred to a bed of gravel and brickearth, and the boulder clay lies 14 ft. below it.

According therefore to Professor Boswell, the Mousterian age of the chalky boulder clay is still in question. The overlying gravels, which are accepted as glacial (pp. 45, 59), contain paleolithic implements of various types.

The area is traversed by a series of drift-filled river valleys, which descend below sea level; Professor Boswell compares them to the Danish fohrden which were attributed by Gagel to erosion by subglacial rivers; the writer, however, regarded the Danish evidence as in favour of the formation of the fohrde by interglacial rivers acting along the line of pre-glacial valleys. J. W. G.

GEOLOGISCHES PRAKTIKUM. By the late RUDOLF SOKOLT. pp. 248, with 127 figures. Berlin: Borntraeger, 1927.

THE first few pages of this book are occupied by a short sketch of what the author considered to be the proper training for a geologist. The reader may well be led to wonder at what ages a German geological student begins and ends his education, because the subjects here indicated as necessary would afford occupation for several University courses as understood in this country.

The rest of the book is occupied mainly by descriptions of the construction and uses of various geological instruments and by chapters on methods of mapping and section-drawing, interspersed with sections on stratigraphy, petrology, and so forth. The cutting of rock-sections is also discussed. The weakest point of all such books is that they tend to give an exaggerated idea of the amount of apparatus and equipment necessary in geology, and thus to scare off students from a science which does not in reality need an elaborate outfit, except in highly specialized cases.

LATE TERTIARY IGNEOUS ROCKS OF THE LOWER CHINDWIN REGION, BURMA. By E. S. PINFOLD, A. E. DAY, L. D. STAMP, and H. L. CHHIBBER. *Trans. Mining and Geol. Inst. India*, vol. xxi, 1927, pp. 145–225.

THE IGNEOUS ROCKS OF THE MOUNT POPA REGION, BURMA. By H. L. CHHIBBER, ibid., pp. 226–310.

THESE two profusely illustrated memoirs afford an interesting account of certain igneous rocks which have accompanied earth-movements of comparatively late date in the geological history of Burma. The first group occur either as conical hills or as walls surrounding crater-lakes, or less frequently interbedded with Irrawadian sands. The occurrences are arranged along two tectonic lines, and include basalts, andesites, and rhyolites. Very complete petrographical descriptions are given.

The rocks of the Mount Popa region are divisible into five stages, of which the middle members are sub-aqueous and of Irrawadian (Pliocene) age. The general sequence is from intermediate to acid, with a final return to a basic phase.

Both areas and the dolerites of the Pegu Yoma constitute a definitely calc-alkaline petrographical province, in strong contrast to the rocks of the Kabwet area, which are alkaline.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

"Across Canada with Princeton." By E. B. Bailey, M.C., B.A. An explanation was offered of the scope of the Princeton Summer School, a recent creation of Professor R. M. Field, of Princeton University, N.J. The school owns a Pullman car, and with a couple of foreign guests devotes a yearly six weeks to carefully prepared geological travel. A few words sketched North America as a magnified mirror image of much of Europe, and emphasized the Appalachian crossing of mountain chains and of stratigraphical facies (*Nature*, 5th November, 1927). The following subjects were then discussed, with lantern illustrations: Palaeozoic submarine landslips at Quebec; the origin and history of the Great Lakes; Niagara; the flat pre-Cambrian rocks of Lake Superior; the silver and pre-Cambrian glacial beds of Cobalt; the nickel, cauldron-subsidence and ring-dykes of Sudbury; the gold of Porcupine; the Great Plains; the Foot-hills and the Turner oil-field; the thrusts, folds, dolomitization, glaciers, beauties, and bears of the Rockies; the granite range of British Columbia and various aspects of Vancouver Island.

Geologists' Association.

2nd December, 1927.

"The 200-ft. Platform in the London Basin." By S. W. Wooldridge.

In a former communication (*Proc. Geol. Assoc.*, vol. xxxviii, 1927, p. 49) it was shown that various high-level deposits of sand and shingle round London are of Lower Pliocene age and that the general summit plane of the higher hills of the central Basin—the "Upper Plain" of McKenny Hughes—can be accepted as a datum of this stage.

In the paper now submitted, the post-Lenhamian rejuvenation of the river-system is traced and emphasis laid upon the widespread occurrence of a dissected plain at 200–250 ft. O.D. which may be appropriately referred to as the "Lower Plain". This feature is traced in the several water-gaps of the Northern Weald, and brief reference is made to its occurrence in the country lying south of the North Downs escarpment, especially in the Ashford district. It is shown to be a dominant feature throughout the London Basin, east of the river Colne, and north of the Thames it proves to be the platform on which the bulk of the glacial deposits were lodged. Nevertheless, it is certainly pre-glacial in age, since the rivers had cut trenches of varying depth in it before the advance of the ice. In the light of this and other facts its age is discussed and it is interpreted as a subaerial base-level of late Pliocene or early Pleistocene age. Its possible relation to the supposedly marine Westleton Beds of eastern Essex receives attention and it is further suggested that the plain may be correlative with the Milazzian raised-beach of the Mediterranean region.

Some description is given of the deposits resting on the plain, and attention is called to the prevalence of drainage modifications on its surface.

From the facts adduced in this and the previous paper, it is claimed that an outline of a general denudation-chronology for Southern Britain can be established. The sculpture of the country appears to have been controlled by a series of " uplifts " essentially eustatic in their nature. If this fact can be fully established a number of valuable simplifying generalizations become possible.

" On the Rock Groups of Jersey, with special reference to Intrusive Phenomena at Ronez." By A. K. Wells and S. W. Wooldridge.

In the paper the relations of the several rock groups occurring in Jersey are reviewed. Special study has been made of the intrusions, of which an extensive and varied suite occurs in the island. The high sea-cliffs, wide wave-cut platforms and large quarries which have been in active work for a long time have combined to afford exposures, unparalleled elsewhere in Britain, of gabbro-granite complexes which penetrate the bedded succession in the north, south-east, and south-west of the island. The isolation of the granite outcrops is due to the partial unroofing of the Channel Islands bathylith. Each of the major intrusions is a cupola with nearly vertical sides and highly irregular upper surface penetrated by roof-pendants of gabbro and rhyolite-lavas. The acid magma has stoped its way into the gabbro which is regarded as a sheet, thinning eastwards, originally covering all but the north-eastern corner of the island, and extending westwards an unknown distance. It has been reduced to a number of small isolated outcrops by denudation and the invasion of granite magma from beneath. The admirably exposed contacts clearly demonstrate the several stages of the stoping process and the importance of the process in magmatic injection.

By the progressive assimilation of gabbroic xenoliths, which are seen in all stages of dissolution, hybrid rock types have been produced.

Sections of the paper deal with the relation of the granite to roof- and wall-rock, and with the petrology of the normal and hybrid rocks. It is shown that some of the faults traced on existing maps are the normal, steeply plunging contacts of the cupolas.

A small acid complex at Mt. Orgeuil in the south of the island is probably older than the major plutonic intrusions, and is cut by sheets of granite-porphyry and granophyre formerly regarded as later rhyolite flows. The sheets apparently postdate the extrusive phase. Of presumably the same age is the miniature boss of granophyre at Fort Regent (the Fort Regent " granite " of other writers).

The age of the Jersey intrusives cannot be directly determined, but such indirect evidence as is available is evaluated, and the several possibilities are critically examined.

General accounts of the geology of Jersey will be found in the *Handbuch der regionalen Geologie*, 111, 1; The British Isles, Appendix iv, The Channel Islands, by Dr. John Parkinson; and *Proc. Geol. Assoc.*, xxxii, 1921, p. 151, by Dr. G. H. Plymen.

Reference should also be made to two papers by Mr. A. W. Groves, bearing on the age of the Channel Island granites, in the GEOL. MAG., 1927, pp. 241 and 457.

YORKSHIRE GEOLOGICAL SOCIETY.

19*th November*, 1927.

"Extracts from Carboniferous Zones Committee Report on Field Work, 1927." By W. S. Bisat.

This Committee was formed at a meeting of the Society held on 12th March, 1927, with the object of promoting the study in the field of Carboniferous Zones.

The deserted brickpits at Whimney Gill on the hillside immediately to the south-east of Skipton proved to be an important exposure of beds of P_2 age (roughly the *spirale* zone) with numerous fossiliferous limestone bullions on at least two horizons, and with fine exposures of the upper part of the Bowland Shales, showing the succession from the limy shales of P_2 up through the argillaceous shales of lower E as far as the grits capping the hill. The parallel section in Eastby Beck was reinvestigated, and valuable material obtained from bullions. Much work still requires to be done, especially in the upper beds. P_2 is an extremely important horizon in view of the very widespread occurrence of the zonal fossils. These are already known as far west as Oklahoma (U.S.A.), as far east as Silesia, and as far south as the north of Africa.

The zonal sequence in P_2 is not yet fully known, although it seems evident that it is in this Skipton and Clitheroe area that the best known European exposures occur. The following is put forward as a working table, based on sections in the Skipton and Clitheroe districts :—

ZONAL GONIATITES.

Zone.

E. (7) *Cravenoceras leion* (sp. nov.) and early *Eum. pseudobilingue.*
(6) *Cravenites* (gen. nov.) sp. and *Sagittoceras coronula* (Roemer).
(5) *Goniatites newsomi* (Smith) late form (cf. *spirale s. str.*) and *Sagittoceras meslerianum* (Girty).
(4) *Goniatites subcircularis* and *Gon. crenistria holmesi* (subspec. nov.).

P_2 (3) *Gon. regularis* (sp. nov.) and *G. newsomi* and *Sag. meslerianum* (early form).
(2) *Gon. splendens* (sp. nov.) and *Sagittoceras burhennei* (Schmidt).
(1) *Gon. granosum* and undescribed species.

The above sequence seems clear, but we are still left without precise knowledge of the position of the band seen at Dinckley containing a mixture of *G. newsomi* (early form), *G. crenistriatus* (sp. nov.) and *G. granosum.* This band may be between (1) and (2) or below (1). *G. crenistriatus* or a close ally is also seen in Sunter Gill, Flasby.

As a result of the Appletreewick excursion (Easter, 1927) the horizon of the knoll limestone of Cracoe is gradually becoming clearer, and it is evident that most of the knoll limestones lie below P_2 and are in the *Beyrichoceras* zone, where goniatites are very infrequent. It is evident, however, that below P there are traces of forms allied to *G. crenistria* or *G. striatus*, but the material is far too scanty at present for description. The quarry on the roadside west of Elbolton, near Esco House, contains goniatites of this age and requires careful working. The knoll limestones reach the horizon P to the north-west of Burnsall. The unconformable juncton of the knoll limestone and shale is well seen in Waterspout Beck. The shales here are mainly of P_2 and E age, but may descend into P_1. Compared with the beds of the same age nearer Skipton they seem relatively unfossiliferous, and there is a good deal of argillaceous shale below the *granosum* bed. Below these shales, and at the summit of a waterfall occurs a band with abundant *Posidonomya becheri* and undetermined goniatites of the striatoid group. This bed is presumably high in P_1.

There are two factors which make the Carboniferous exposures of the Pennine area of the greatest importance, and these are :—

(1) That the exposures are probably the best in Western Europe ;

(2) That in our "knoll" areas we have an unparalleled opportunity for studying the junction of the two great phases of the Lower Carboniferous—Culm and Carb. Limestone.

It seems desirable, therefore, that the Carb. Zones Committee of this Society should continue in existence, and that more of our members should realize that we are only beginning to approach the greater problems involved in the subject.

Glasgow Geological Society.

13th *October*, 1927.

"The North Ayrshire Sequence of Calciferous Sandstone Volcanic Rocks." By J. E. Richey, B.A., H.M. Geological Survey.

The area dealt with forms a large part of the Clyde Volcanic Plateau south of the River Clyde, which is in course of investigation by the Geological Survey. The thickness of the volcanic series where well developed is 1,000 ft. and upwards. Its time range is comparatively brief, probably only from the upper part of the Cement-stone Group to the lower part of the Oil-Shale Group. There are two groups—a lower, consisting essentially of felspathic macroporphyritic basalts (Markle type), and an upper, of which olivine-rich microporphyritic basalts (Dalmeny type) are the most widespread constituent. The upper group thickens out greatly towards the east by the intercalation of other lava types. Of the latter, trachytic lavas and ashes form extensive outcrops, although restricted to a definite belt along which trachyte-filled vents are scattered. They have presumably not proceeded far from their vents of origin. A comparison is made of the above sequence with those in other parts of Scotland.

Presidential Address: "Scottish Carboniferous Stratigraphy." By Murray Macgregor, M.A., B.Sc., Assistant Director, H.M. Geological Survey, Part I.

The address was based largely on the many bore-records obtained in recent years, which check and supplement the evidence from natural sections. The various sub-divisions and index horizons used for purposes of detailed comparative stratigraphy in the Scottish Carboniferous succession were dealt with, and the lithological and palaeontological criteria made use of in establishing correlations between different areas were discussed. The vertical distribution of the chief rock types was illustrated by diagrams showing for a typical area like the Central Coalfield the relative proportions in which the following types of sediment occur: (1) arenaceous beds, (2) shales, marls, ironstones, (3) coals, fireclays, oilshales, (4) limestones and shell-beds. The important economic horizons were indicated and a series of comparative vertical sections of the Scottish Coalfields shown to illustrate the variation in the succession in the different districts. Among special points dealt with were: (1) *The evidence for a rise in the stratigraphical level of the workable coals.* In Fife and Mid-Lothian the lower part of the Productive Coal-Measures contains the greater proportion of workable coal seams, while in the south-west of the Central Coalfield and in Ayrshire the upper part is the richer. In South Ayrshire, again, coals of workable thickness extend upwards into the Barren Red Measures. In the Canonbie Sequence there are both Lanarkian and Westphalian coals; (2) *The variations in thickness shown by each sub-division of the Scottish Carboniferous Rocks.* These were analysed and shown to be due to attenuation. The Carboniferous Series, for example, may reach a thickness of 3,400 ft. in parts of Fife, but on the south side of the Central Coalfield it is reduced to 720 ft., and in parts of Ayrshire it may only be 100 ft. thick. These variations were followed out in detail and appear to indicate differential crustal movements over the region of deposition, producing relatively stable and unstable areas. The "shallows" and "deeps" of Carboniferous Limestone times were briefly indicated and the suggestion advanced that the "shallow" areas represent the land barriers that existed in Calciferous Sandstone times.

MINERALOGICAL SOCIETY.

Anniversary Meeting.—1st November.

Dr. L. J. Spencer: "Specific gravities of minerals: An index of some recent determinations."

Specific gravity as determined by heavy liquids affords a convenient first aid in the determination of minerals. 2,277 determined values collected from the recent mineralogical literature are arranged numerically, and an alphabetical index of mineral names gives the minimum and maximum values for each mineral.

Dr. L. J. Spencer: "South African occurrences of willemite. Fluorescence of willemite and some other zinc minerals in ultra-violet rays."

Willemite is described from Broken Hill and two other localities in Northern Rhodesia where it appears to be of abundant occurrence, and from Guchab in South-West Africa. Unlike the willemite of Franklin Furnace, New Jersey, some of these do not fluoresce in ultra-violet light. Fluorescence is not a constant and essential character of a mineral species, and it evidently depends on the presence of admixed impurities.

Dr. T. V. M. Rao: "A Study of Bauxite."

Specimens of laterite from India, Gold Coast, and other countries were described. It was shown that laterite was a rock largely composed of the mineral bauxite, which had a definite composition corresponding to the formula $Al_2O_3.2H_2O$. Details of an experiment to trace the process of laterization in nature were also given.

Dr. P. K. Ghosh: "On the biotite-bearing greenstones and on a rhyolitic pumice in the metamorphic aureole of the Falmouth granite."

The biotite constituent, which has so far been ascribed to the metamorphic action of the Armorican granite on the pre-existing greenstone, is proved to be the undigested and residual part of the slate fragments stoped by the "greenstone" magma at the time of its intrusion. Rhyolitic pumice is noted for the first time in this region and its mineralogical characters are described.

The annual general meeting of the Mineralogical Society was held on 1st November, and the following officers and members of council were elected: *President*: Dr. G. T. Prior. *Vice-Presidents*: Sir J. S. Flett, Sir T. H. Holland. *Treasurer*: Mr. F. N. Ashcroft. *General Secretary*: Mr. W. Campbell Smith (Natural History Museum, South Kensington, S.W. 7). *Foreign Secretary*: Dr. J. W. Evans. *Editor*: Dr. L. J. Spencer. *Ordinary Members of Council*: Professor P. G. H. Boswell, Professor H. L. Bowman, Mr. A. J. Bull, Mr. T. Crook, Professor C. G. Cullis, Professor W. T. Gordon, Dr. H. F. Harwood, Mr. L. Hawkes, Professor H. Hilton, Dr. W. F. P. McLintock, Dr. G. F. Herbert Smith, Dr. H. H. Thomas.

CORRESPONDENCE.

CAMBRIAN ROCKS NEAR THE WREKIN.

Sir,—In the course of the Geological Survey of Sheet 152 New Series (Shrewsbury), I have had occasion to examine the district lying between the Wrekin and Charlton Hill and have found some new exposures of Cambrian beds. The results so far obtained may be of interest.

The area in question lies between the north-eastward continuation of the Church Stretton Fault and the Wrekin Fault. It is drained by Dryton Brook and its tributary Rushton Brook.

The basal Cambrian quartzite is well known to crop out at Charlton Hill and at Rushton, between that hill and the Wrekin. Its outcrop has now been traced through the intervening ground, and is found to be broken by a number of transverse faults. The quartzite is succeeded by about 500 feet of Comley Sandstone, the upper part of which is well exposed in a gully at the head of Dryton Brook, and here the *Callavia* Sandstone and overlying *Olenellus* Limestone, both abundantly fossiliferous, have been detected. There are also indications of several other fossiliferous Lower Cambrian horizons comparable with those worked out by Mr. E. S. Cobbold in the Comley area.

These beds are overlain by Middle Cambrian glauconitic grits and shales, in which a calcareous band, exposed in Rushton Brook, has yielded a well-preserved Paradoxidian fauna. The grits crop out also round the southern end of Charlton Hill.

Along the east flank of Charlton Hill some dark shales yield Cambrian brachiopods and ostracods; but their position in the sequence is at present obscure. Other shales with brachiopods are in contact with glauconitic grit between Upper Dryton Brook and Rushton Brook.

Shineton shales are exposed farther down stream, just north of the outcrop of the Coal Measures of the Dryton Coalfield.

It is proposed to make a more detailed examination of this area next year; meanwhile Mr. Cobbold is studying the fossils already obtained.

R. W. Pocock.

28 Jermyn Street, S.W. 1.
16th November, 1927.

CLIMATIC CORRELATION OF RAISED BEACHES.

Sir,—The letter by Mr. W. B. Wright, in your November issue, on the subject of Raised Beaches is most interesting, and I wish to thank him for his valuable criticism and advice.

In reply, I would like to make the following comments:—

(1) The conclusions which I reached in my paper refer essentially

to the particular raised beach sections discussed there, and much further work is admittedly necessary before a very general application can be made.

The following facts, however, seem quite plain, whatever their meaning may be.

That in the unglaciated parts of southern England there are certainly two raised beaches which resemble the 10 ft. pre-glacial beach in that they maintain a constant level over a large area, but they differ from that beach by being at the heights of 30 ft. and 60 ft.

The 60 ft. beach contains a markedly warm fauna with glacial erratics, which presumably were derived from earlier glacial deposits.

The 30 ft. beach overlies the lower part of the 60 ft. beach, and presumably is younger than it. None of these beaches can be correlated with the 10 ft. pre-glacial beach.

It is not, therefore, Mr. Wright's 10 ft. pre-glacial beach which has been correlated with the Scottish beaches, but these later deposits occurring with the pre-glacial beach in the same area.

The 30 ft. and 60 ft. beaches are, in my opinion, present in Gower, where they contain (as they do elsewhere), a well-marked littoral fauna ; and thus also do they differ from the 10 ft. pre-glacial beach which, I understand from Mr. Wright's work, contains no fauna.

(2) Mr. Hinxman suggests in his paper that at the head of Loch Torridon, and elsewhere in Scotland, there is evidence of a readvance of the valley-glaciers " after the appearance of Neolithic man in Scotland " (presumably after the 25 ft. raised beach).

My wording on page 436 should have read : " at least after the 25 ft. beach ", instead of " between 50 ft. and 25 ft. times ".

(3) The question Mr. Wright raises about kitchen-middens is undoubtedly important, and the possibility of material from them being incorporated in certain collections has not been forgotten. It should be noted, moreover, that the species most used for climatic purposes are forms under $\frac{1}{4}$ inch in size.

D. BADEN-POWELL.

OXFORD.
November, 1927.